A Computer-Assisted Analysis for Thermodynamic Processes and Cycles

by

AbdulGhani Abdullah Al-Farayedhi

A Thesis Presented to the

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DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

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In

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King Fahd University of Petroleum and Minerals (Saudi Arabia), 1979

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بسم الله الرحمن الرحيم

THIS THESIS IS DEDICTED TO MY

MOTHER

WIFE

DAUGHTER

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NOMENCLATURE

A	:	area
A_r	:	area ratio
c_p	:	constant pressure specific heat
c_v	:	constant volume specific heat
CPLTR	:	$c_p.\ell n\ T_r$
CPLVR	:	$c_p.\ell n\ V_r$
CVLPR	:	$c_v.\ell n\ P_r$
CVLTR	:	$c_v.\ell n\ T_r$
CVLVR	:	$c_v.\ell n\ V_r$
E	:	total energy
ΔE	:	net energy change for a process
$\dot{E}$	:	rate of total energy
$\Delta\dot{E}$	:	rate of change of total energy
e	:	specific energy
Δe	:	specific energy change
$\dot{e}$	:	rate of change of specific energy
$\Delta\dot{e}$	:	rate of change of specific energy
g	:	gravitational acceleration
g_c	:	constant that relates force, mass, length, and time in Newton's second law of motion

H : enthalpy

ΔH : enthalpy change

h : specific enthalpy

Δh : specific enthalpy change

K : ratio of specific heats, c_p/c_v

ΔKE : change in kinetic energy

ke : specific kinetic energy

Δke : specific kinetic energy change

LPR : $\ell n\ P_r$

LTR : $\ell n\ T_r$

LVR : $\ell n\ V_r$

M : molecular weight

m : mass

$\dot{m}$: mass flow rate

N : number of moles

n : polytropic constant

P : pressure

ΔP : pressure change

P_r : pressure ratio

PE : potential energy

ΔPE : change in potential energy

pe	:	specific potential energy
Δpe	:	specific potential energy change
PV	:	P.V
ΔPV	:	change in PV
Pv	:	P.v
ΔPv	:	change in Pv
Q	:	heat transfer
q	:	heat transfer per unit mass
$\dot{Q}$	:	heat transfer rate
$\dot{q}$	:	rate of heat transfer per unit mass
R	:	gas constant for a particular gas
$\overline{R}$	:	universal gas constant
RLPR	:	$R.\ell n\ P_r$
RLVR	:	$R.\ell n\ V_r$
S	:	entropy
ΔS	:	entropy change
s	:	specific entropy
Δs	:	specific entropy change

T	:	temperature
ΔT	:	temperature change
T_r	:	temperature ratio
TDS	:	final temperature change due to irreversibilities
Δt	:	elapsed time
U	:	internal energy
ΔU	:	internal energy change
u	:	specific internal energy
Δu	:	specific internal energy change
V	:	volume
$\dot{V}$	:	volumetric flow rate
ΔV	:	change in volume
V_r	:	volume ratio
$\vec{V}$	:	velocity
$\vec{V}_r$	:	velocity ratio
v	:	specific volume
Δv	:	specific volume change
$\bar{v}$	:	specific molal volume
W	:	work transfer

W_a : external work

W_f : flow work or boundary work

$\dot{W}$: rate of work transfer or power

$\dot{W}_a$: rate of external work

$\dot{W}_f$: rate of flow work

w : work transfer per unit mass

w_a : external work per unit mass

w_f : flow work per unit mass or boundary work per unit mass

$\dot{w}$: rate of work transfer per unit mass or power per unit mass

$\dot{w}_a$: rate of external work per unit mass

$\dot{w}_f$: rate of flow work per unit mass

Z : elevation

SUBSCRIPTS:

a : external term

c : constant

I : initial state of a process

F : final state of a process

f : flow term or boundary term

p : constant pressure

r : ratio

s : final state of isentropic process

v : constant volume

GREEK SYMBOLS AND SPECIAL NOTATION:

Δ : Change in property

η : efficiency

ρ : density

ABSTRACT

The computer-assisted technique for analyzing numerical problems has been made available recently in several engineering disciplines. This thesis describes the development of a generalized computer program aimed to assist in the analysis and syntheses of problems in engineering thermodynamics.

The computer program developed is intended to solve ideal gas related problems in closed systems, as well as those in steady-state steady flow processes. In addition, the program can handle both intensive and extensive properties as given by the user.

One of the main features of the program is that the output contains a step procedure used in the computational routines. In other words, besides a numerical output, the algebraic equations that have been used in the computation are given in a sequential order. This enables those who desire to know how the results are obtained.

The programming language used in this program is FORTRAN IV. The program is written in an interactive mode to be used in conjunction with the terminals connected to the IBM 370/158 computer installed at University of Petroleum and Minerals.

In order to facilitate the use of the program, a manual which includes a number of illustrative examples has been compiled. Users must prepare to answer each question prompted on the terminal by entering proper codes along with data provided by the problem statements. Answering all questions and inputting data correspondingly will direct the computer program to run through its logical routines until it arrives at a final group of expressions. From these, useful information can be obtained.

1. INTRODUCTION

GENERAL

Engineering Thermodynamics which deals with the energy and its transformation, is one of the basic courses in the engineering undergraduate curriculum. In this course, students learn how to apply the fundamental laws and property relationships in order to study the behavior of thermodynamic systems influenced by certain changes in the system and its surroundings.

In dealing with problems and solutions, average students who have a reasonable understanding of basic laws and concepts of thermodynamics, from time to time, are lack of confidence in the results of their computation. This is especially true, when a problem involves multiple steps, where several equations need be deduced. On the other hand, some students may wish to study the efect due to the change of certain parameters on the behavior of a system. Usually the latter requires repetitive steps in solution involving different sets of data. It certainly can become time consuming and non-creative. Therefore, an attemp is made to develop a computer-assisted method to facilitate the analysis of thermodynamic problems. The intent is to supplement rather than replace traditional pedagogical techniques in thermodynamics.

Generally the task of developing a general program that can solve a large variety of problems is much more complicated than developing a program for specific cases. This is because of that the solution path for specific application is generally well defined, while in general programming, the solution paths for all possible cases must be defined according to input data. The computer must be instructed precisely how to carry out all required operations until an unique solution path can be selected.

The primary objective of this thesis is to develop a generalized computer program to aid in the analysis and synthesis of a class of thermodynamic processes and cycles. In order to facilitate the analysis, the style of the program has been made inductive and conductive, so that, through an interactive mode, the computer can request from its user for inputs in terms of whether the thermodynamic system is open or closed, whether the processes are isothermal, isobaric, isentropic, isometric, polytropic, or unspecified; and whether the working device is turbine, compressor, nozzle, diffuser, heat exchanger, piston-cylinder assembly, or others. These inputs, in fact, serve to assist the computer to search through its logical routines until it arrives at a final group of expressions from which useful information can be obtained. The main features of this program can be summarized as follows:

1) The program is structured in an interactive mode.
2) The data entry is free formated.
3) The program accepts intensive and extensive properties, as well as time rate properties.

4) The program accepts both English and S.I.Units.

5) The program solves both open system (steady-flow) and closed system (non-flow) problems.

6) The program provides the users with a list of the algebraic equations that have been used sequentially in the computation in order to assist them to find out how the results are obtained.

Thus, the program will be a valuable tool in the analysis of thermodynamics problems. The usefulness of this tool will be demonstrated by giving confidence to the beginners in learning the subject and providing encouragement to those experienced in the subject to go beyond problem solving into creative design studies.

LITERATURE SURVEY

The availability of general purpose computer programs that can solve a great variety of problems exists in several engineering disciplines. Stagg and El-Abiad [1] presented computer techniques in power system analyses on short circuit, load flow and power systems stability. Although they did not include computer programs in their text, many flow charts were presented. Streeter and Wylie [2] provided a computer program for analyzing the hydraulic transient phenomenon by the method of characteristics. The program can handle a number of cases in which pressure pulses can be calculated for given boundary conditions involving valves, pumps, accumulators, pipe junctions, and vapor column separations normally associated with the hydraulic system design. They [3] also included a set of FORTRAN programs for solving simple pipe flow, pipe network,.and unsteady state flow problems in their fluid mechanics text. The Structural Dynamic Research Corporation in the U.S., has made available commercially a finite element program developed for analyzing the dynamic behavior of structures and mechanics under loadings. Adams and Rogers [4] presented a number of small individual (therefore not truly general purpose) programs for solving heat transfer problems by an interactive mode using BASIC language. Isenhour and Jurs [5] included a simple computer program for computation involving ideal gas law. The program can determine pressure, temperature, number of moles or volume of an ideal gas, depending upon which of the four is not known. Mattson, Mark, and MacDonald [6] included an interactive program for computing the experimental molar volume to be used in freshman chemistry course. They also presented a set of computer programs for demonstrating chemical principles by using an interactive mode. In addition, they mentioned that a computer program was just completed for calculating the ideal and Van der Waals pressures of gases by providing the temperature, volume, and number of moles as input. Motard and Lee [7] presented a subroutine of the CHESS program for computing isothermal compressor work. They also presented a subroutine for calculating the output temperature of a fixed-geometry heat exchanger. In addition, they presented a thermodynamic package for supporting their overall program in computing a number of thermodynamic properties. The properties, however, are limited to single phase enthalpy, compressibility factor, dew point temperature and temperature at a given enthalpy.

Stephen Hunter [8] developed for the first time a program which can assist the solution for a number of closed system (non-flow) processes involved in thermodynamics. His program is written in BASIC language for a mini computer (Tektronix 4051). Limited by the capacity of the computer, his program can only handle problems in small scale.

In the 1976 edition of the well known thermodynamics text by Van Wylen and Sonntag [9], there are included in some chapters several assignment problems asking the students to write computer programs for solution of certain specified cases. This development, indeed, made clear the importance of using a computer in studying thermodynamics.

The computer program to be presented in this thesis is written in FORTRAN for the IBM 360/158. Efforts have been concentrated on solving various aspects of ideal gas related problems in non-flow systems as well as those in steady-state steady flow processes and cycles. A solution step procedure has been incorporated in the program in order to assist those who want to know how a problem is solved. Other features such as assisting the user in the analysis of parametric variation on the behavior of a system are presented in detail in this study. The nature of the computer-assisted technique in thermodynamics is believed to be unique. In this regard, a paper was published by the writer with Dr.Pah I.Chen as co-author [10].

2. THE PROGRAM

A block diagram of the general program is shown in Figure 1. The program consists of two major components: a main program and 22 supporting subroutines.

The function of the main program is to control inputs, outputs, computational routines and to validate the input data. Most of the computational steps and data manipulation are carried out in the various subroutines. The flow chart of the main program is included in Appendix K.

A list of subroutines with an explanation of their functions is contained in Table I. The equations that have been referred to in the Table are contained in Appendices B through H.

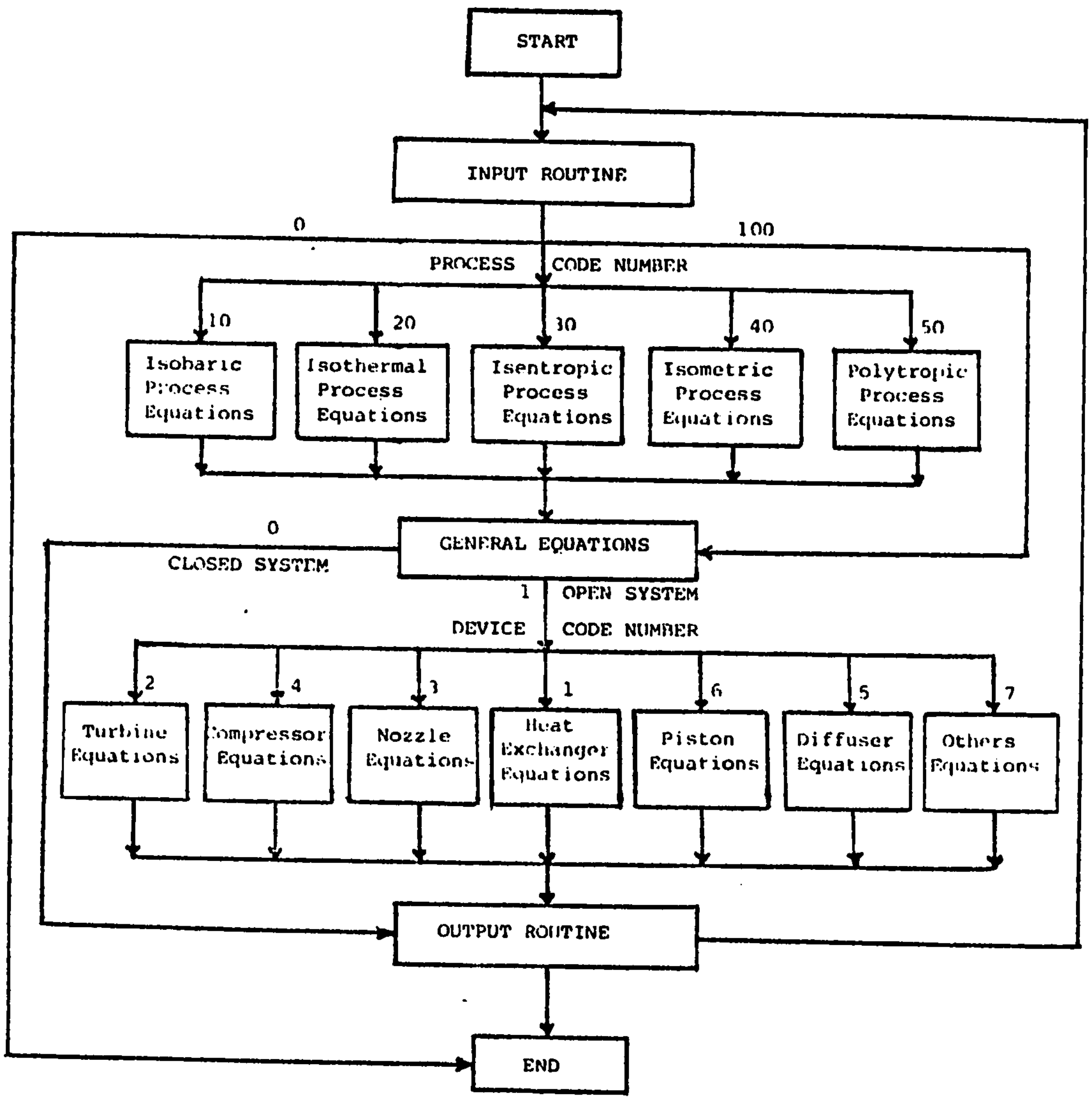


Figure 1: A block diagram of the Computer program

TABLE I : The Subroutines and their Functions

Subroutine Name	*Functions*
SUBIN	Matches code number to variable. Changes variable status from unknown to known. Stores variable values.
OUTPUT	Examines all variables. Assigns a large random value to unknown variables. Prints output matrix.
PART 1	Contains equations 1 through 50.
PART 2	Contains equations 51 through 100.
PART 3	Contains equations 101 through 150.
PART 4	Contains equations 151 through 200.
PART 5	Contains equations 201 through 250.
PART 6	Contains equations 251 through 300.
PART 7	Contains equations 301 through 350.
PART 8	Contains equations 351 through 400.
PART 9	Contains equations 401 through 450.
PART 10	Contains equations 451 through 500.
PART 11	Contains equations 501 through 550.
PART 12	Contains equations 551 through 615.
PART 13	Provides the programs with required constant values.
PRS 1	Contains isobaric process equations.
PRS 2	Contains isothermal process equations.
PRS 3	Contains isentropic process equations.
PRS 4	Contains isometric process equations.
PRS 5	Contains polytropic process equations.
PART 14	Contains devices equations.
PART 15	Contains devices equations.

3. CONDITIONS

GENERAL

When the program was structured, the following conditions have been applied:

1) The working substance behaves as an ideal gas.

2) Thermodynamic systems involved can be steady-state, steady flow as shown in Figure 2, or the non-flow (closed) case as shown in Figure 3.

3) The values of c_p and c_v remain constant.

4) Units in S.I. or English conform to that shown in Appendix A.

5) Sign conventions: heat added to a system and work done by a system are positive.

OPEN SYSTEM

For the open system as shown in Figure 2, the following conditions are made:

1) Flow rate is steady.

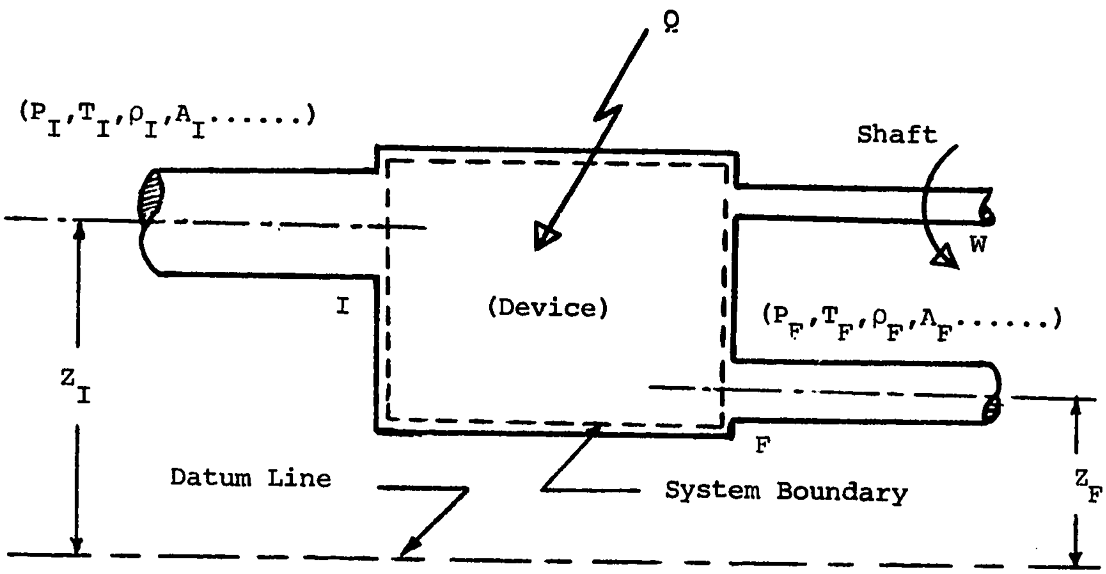


Figure 2: A Steady-state Steady-flow System

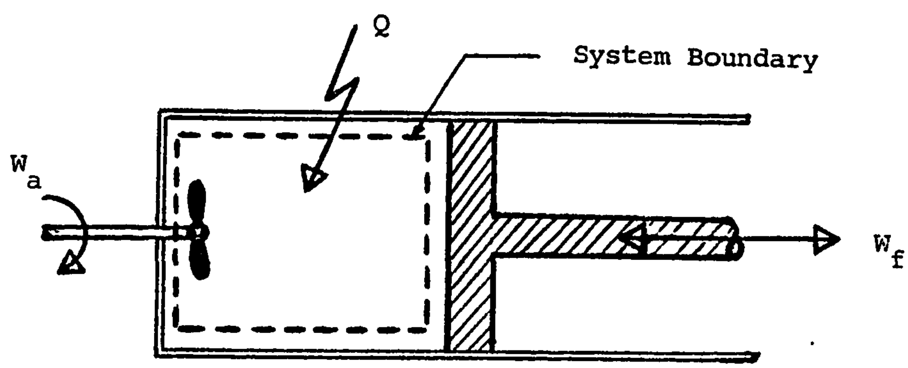


Figure 3: A Closed System

2) Mass flow rate is one-dimensional.

3) First law is given by:

$$W = Q - \Delta H - \Delta KE - \Delta PE \qquad \text{(a)}$$

4) Second law is given by:

$$T\Delta S = \Delta H - V\Delta P \qquad \text{(b)}$$

5) The device efficiencies are based on adiabatic conditions.

6) Pressure, density, and temperature ratios of devices should be below the critical conditions, i.e. the flow is subsonic.

CLOSED SYSTEM

For the closed system as shown in Figure 3, the following conditions are applied:

1) Mass is constant.

2) Change of kinetic and potential energy is negligible.

3) First law is given by:

$$W = Q + \Delta U, \quad W = W_f + W_a \qquad \text{(c)}$$

4) Second law is given by:

$$T\Delta S = \Delta U + P\Delta V \qquad \text{(d)}$$

4. THERMODYNAMIC EQUATIONS

Thermodynamic equations and expressions which are involved in the analysis of thermodynamic systems have been grouped according to their applicability. General expressions which are applicable to various types of processes and devices for open and closed systems are listed in Appendix B. More specific expressions for isobaric, isentropic, isometric, isothermal, polytropic processes and devices are listed in Appendices C, D, E, F, G and H respectively.

In the program, each equation has been written in different forms so that each of the variables can be expressed in terms of other variables contained in the equation. Each equation has been assigned a set of numbers. The first number indicates that the equation is solved for the first variable. Similarly for the second and third numbers. When the numbers are bracketted, the same rule applies except that the final state values are used. For example, take the following equation:

$$H = U + PV \qquad \text{(e)}$$

The corresponding numbers for the above equation are:

353, 355, 357, [354, 356, 358].

Hence, equation 355 has the following form:

$$U_I = H_I - PV_I \qquad \text{(f)}$$

And, equation 358 has the following form:

$$PV_F = H_F - U_F \qquad \text{(g)}$$

5. VARIABLE DATA MANIPULATION

Figure 4 contains a matrix of thermodynamic variables, constants and some combined variables to be used as inputs. Each variable in the matrix is given an unique code number. For example, code number 9 represents specific enthalpy h. Subscripted variables are used in order to identify their appropriate states. Three types of subscripts are used, I, F, and S. The subscript I denotes variables at the initial state of the process, while F and S denote the variables at the actual and isentropic final state of the process respectively. For example, as shown in Figure 5, T(I) is the temperature of the initial state, T(F) is the actual temperature at the final state, and T(S) is the isentropic final temperature of the process.

Constant variables, such as c_p, and c_v, carry the subscript of I, while the process variables, such as ΔT, W, Q, P_r, and LPR determined by the initial and final state properties have been subscripted to either F or S according to the input data. Appendix A contains the allowable subscripts which are assigned to each variable.

Thus, three parameters are needed for the computer to describe the input variable data: variable code number, variable value and its corresponding subscript. When these data have been entered the computer

(1)* P	(2) T	(3) m	(4) V	(5) v	(6) V_m
(7) ρ	(8) H	(9) h	(10) S	(11) s	(12) U
(13) u	(14) PE	(15) pe	(16) KE	(17) ke	(18) E
(19) e	(20) Q	(21) q	(22) R	(23) Ru	(24) C_p
(25) C_v	(26) K	(27) n	(28) M	(29) N_m	(30) $\vec{V}$
(31) Z	(32) g	(33) W	(34) w	(35) V_r	(36) T_r
(37) P_r	(38) ΔT	(39) ΔP	(40) ΔV	(41) Δv	(42) ΔH
(43) Δh	(44) ΔU	(45) Δu	(46) ΔS	(47) Δs	(48) ΔE
(49) Δe	(50) ΔKE	(51) Δke	(52) ΔPE	(53) Δpe	(54) $\ell n P_r$
(55) $\ell n\ T_r$	(56) $\ell n\ V_r$	(57) $R\ \ell n\ P_r$	(58) $R\ \ell n\ V_r$	(59) $C_v\ \ell n\ T_r$	(60) $C_p \ell n\ T_r$
(61) $C_p \ell n\ V_r$	(62) $C_v \ell n\ P_r$	(63) $C_v \ell n\ V_r$	(64) PV	(65) Pv	(66) ΔPV
(67) Δpv	(68) Q_f	(69) Q_a	(70) W_f	(71) W_a	(72) q_f
(73) q_a	(74) w_f	(75) w_a	(76) A	(77) t	(78) $\dot{m}$
(79) $\dot{V}$	(80) $\dot{E}$	(81) $\dot{e}$	(82) $\dot{Q}$	(83) $\dot{q}$	(84) $\dot{W}$
(85) $\dot{w}$	(86) $\Delta\dot{E}$	(87) $\Delta\dot{e}$	(88) $\dot{Q}_f$	(89) $\dot{Q}_a$	(90) $\dot{W}_f$
(91) $\dot{W}_a$	(92) $\dot{q}_f$	(93) $\dot{q}_a$	(94) $\dot{w}_f$	(95) $\dot{w}_a$	(96) $\vec{V}_r$
(97) A_r	(98) g_c	(99) η			

* *Numbers in brackets represents the code number of each variable.*

Figure 4. The Input Matrix

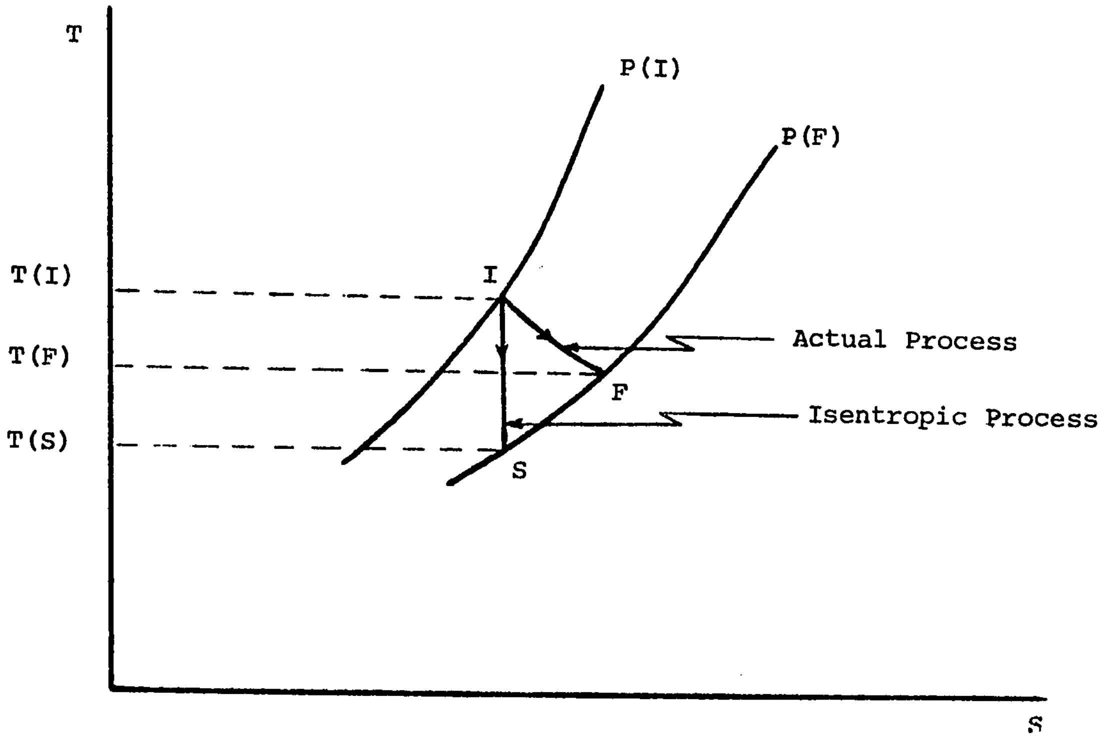


Figure 5: An Illustration of Initial and
Final States of a Process

calls for the subroutine SUBIN for the purpose of,

a) changing the variable status from unknown to known by using VST, variable status tester;

b) matching the variable code number to its variable name; and,

c) storing the variable value

The technique used in the subroutine SUBIN (refer to the block diagram as shown in Figure 6) is based on the flow diagram as shown in Appendix L. In order to explain how SUBIN can handle the input data, let us consider that J, XX, and A have been entered for a specific variable. Firstly, SUBIN examines the value of the subscript A. If A = F, or A = 0, then its VST (to be explained in detail in next chapter) changes to J, and B is equated to F. If A = IF5, then its VST changes to J and B is equated to IF5. B is used to distinguish the isentropic from the actual process data. Secondly, the variable code number J is examined. According to Appendix A, the variable whose code number is J, will be equated to XX. As a numerical example, assume

5 150.8 2 .

are entered, then SUBIN will interpret and store these data as V(2) = 150.8.

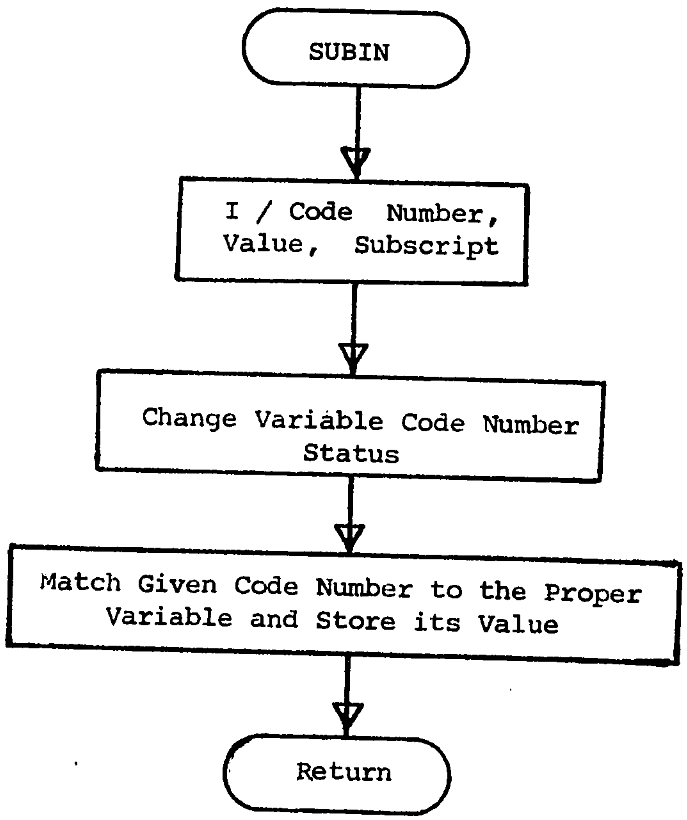


Figure 6: The Block Diagram for SUBIN

6. SOLUTION TECHNIQUE

The technique used in the program is based on examining the status of each varaible contained in each equation. If all the variables on the right hand side of the equal sign are known and the left hand side variable is not known, the computer will compute the unknown value whether it is needed or not. In case one of the variables on the right hand side of the equal sign is unknown, the computer will ignore this equation and move on to the next equation.

In order for the computer to know the status of each variable, a variable status tester, VST, is introduced to each variable. The form of the VST is given by the matrix c(J, A), where J is the variable code number, and A is the subscript which represents the state. If c(J, A) = 0, then it means that the variable value is not known.

Initially, when the program starts, all the VST's are set to zero. But if the value of a certain variable is entered as an input or it has been computed by a previous step its VST changes from 0 to J.

In order to understand how the computer is instructed to solve for unknown variables, let us consider the FORTRAN statements as they appear in a program for equations 1, 2, and 3 (listed in Appendix B).

These statements are:

```
1001  If [C(23,I).NE.23.AND.C(28,I).EQ.28.AND.C(22.I).EQ.22)] GO TO 1
1002  If [C(28,I).NE.28.AND.C(23,I).EQ.23.AND.C(22.I).EQ.22)] GO TO 2
1003  If [C(22,I).NE.22.AND.C(28,I).EQ.28.AND.C(23.I).EQ.23)] GO TO 3
      GO TO 1004
1     RU(I) = MW(I) * R(I)
      C(23,I) = C(23,I) + 23
      JE = JE + 1
      KR(1,JE) = KR(1,JE) + 1
      GO TO 1002
2     MW(I) = RU(I)/R(I)
      C(28,I) = C(28,I) + 28
      JE = JE + 1
      KR (2,JE) = KR(2,JE) + 2
      GO TO 1003
3     R(I) = RU(I)/MW(I)
      C(22,I) = C(22,I) + 22
      JE = JE + 1
      KR (3,JE) = KR(3,JE) + 3
1004  If [C(4,I).NE.4.AND.C(5,I).EQ.5.AND.C(3,I).EQ.3)] GO TO 4
```

Line 01 is the control statement for Equation 1. It contains the VST's of equation 1, and it directs the computer to either equation 1 in line 05, or to the next line depending on the logical expression. The term C(23,I) is the VST for $\overline{R}$ (RU is used for $\overline{R}$ in the program) at the initial state where 23 is the code number which defines this variable, and I indicates initial state. Similarly, C(28, I) is the VST for M at initial state, and C(22, I) is the VST for R at initial state. When the computer reads this line it also examines the logical expression contained. If the VST for $\overline{R}$ is not equal to 23, it indicates that the value of $\overline{R}$ is not known. In addition, the VST of M is equal to 28, and VST of R is equal to 22. According to previous statement, we know that both M and R are known. Therefore, the computer is directed to line 05 to compute the value of $\overline{R}$. Once the value of $\overline{R}$ is computed, the computer goes to the next line where the VST changes from the initial value 0 to a new value, which in this case is 23. This serves to inform the computer that the value of $\overline{R}$ is known. Line 07 increases the step number by one. Then, at line 08 the equation number and the new step number are stored. When the computation of the first equation is done, the computer is directed to line 02 to examine the control statement of equarion 2. As soon as the computer completes testing the first group of equations, it is directed to test a new group of equations in line 04. Consequently, the computer will examine the whole stack of equations one after the other in order to solve for all possible unknown variables.

Since some of the computed values in the first attempt could be used to compute some other unknowns later, a number of loops are incorporated in order to compute for all possible variables on the left hand side of the equations. The number of loops is determined by comparing the number of steps procedure involved in the last two loops. If they are identical then the computer will terminate the looping process. If they are not identical then looping continues until all possible unknown variables are computed.

To explain this by an example, suppose that the data of T_1, P_1, v_1 and $\overline{R}$ have been entered and stored in the program in order to solve for M (by applying equations 2 and 44). Figure 7 shows how the solution is being carried out. In the first loop it starts examining the equations until it arrives at equation 44 in which the VST's are satisfied. So it computes the value of R and stores its value, step number and equation number. The program continues examining the rest of the equations until they have all been involved. In the second loop, the program re-examines the equations from the beginning using all previous stored results. At this time, when the program reaches equation 2, it finds that the VST's are satisfied. This is because the value of R has been stored in the first loop. Hence, the value of M can be computed. In the third loop, the computer finds that no further variables can be computed, so it stops and displays the results.

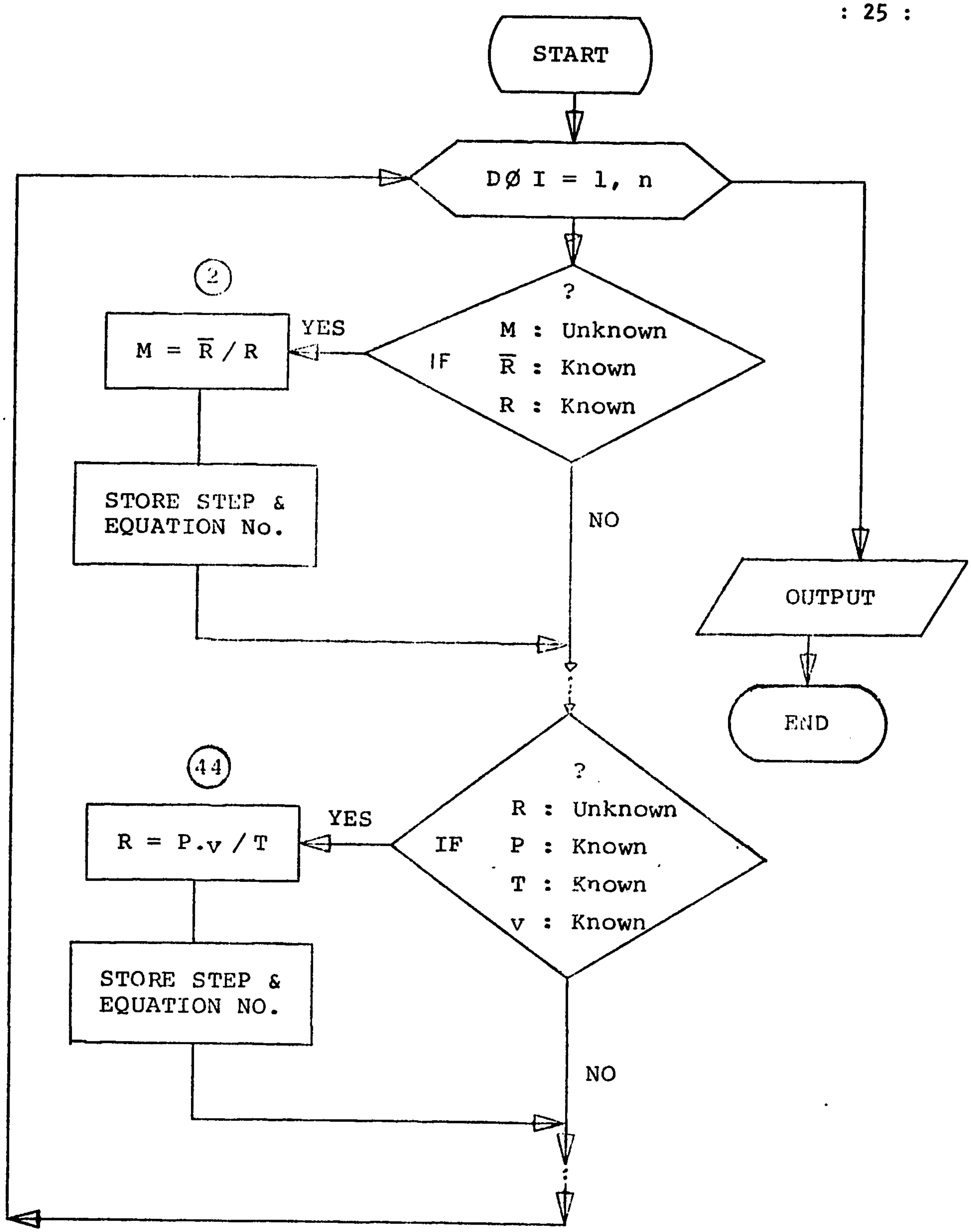


Figure 7 : The Computational Technique Used in the Program

The previous example shows that the solution path of any problem is determined primarily by the input data and secondly by the intermediate results. This implies that there is a need of including each equation and property relationship in all possible forms. In order to increase the effectiveness of the intermediate calculations, the number of terms in each equation is normally kept to three so that, by knowing the values of two terms, the third can be calculated.

7. STEP PROCEDURE

In order to have a record of the equations which have been used consecutively in the computational routine, the matrix KR(N, JE) is used, where N is the equation number (given in Appendices B, C, D, E, F, and G) and JE indicates the number of steps involved in the computation.

Initially, KR(N, JE) is set to zero for every equation. Generally, when the program is directed to an equation, the value of JE is incremented by 1 as it is stored in KR(N, JE). Meanwhile, the matrix KR increases by 1 also to record the step number. For example, KR(20, 7) = 7 shows that equation 20 is used at the seventh step in the computation. If we refer back to Appendix B, we find that the corresponding equation of 20 is:

$$\Delta V = V_F - V_I$$

By this, we learn that the change of volume ΔV has been computed according to the last equation.

8. THERMODYNAMIC PROCESSES

Some common thermodynamic processes used in thermodynamic analysis are listed in Table II. Each process as listed has been assigned an unique code number for the purpose of programming. Based on the code number the computer can pick up the appropriate subroutine that contains all applicable equations to be used in the computation for that process.

To analyze a thermodynamic system which undergoes a certain process, the program requests for units option (S.I. or English units), process code number, initial state, final state, and flow condition of the process. The units option will instruct the program to use the appropriate constants, conversion factors and equations. The main distinction between these two unit options arises from the values of $\overline{R}$, g, g_c. As stated previously, the process code number will enable the program to pick up a corresponding process subroutine in addition to the subroutines which contain the general equations. If the general process code number is used, then the program is directed only to the general equations. In order to store the state and process data, the program asks for I and F of the process. They are used as the arguments in the subscripted variables in the source program, which can be used again in the cyclic analysis. The flow condition of the process involves either an open or a closed system. This input will direct the program to only the applicable group of equations.

TABLE II. Process Code Numbers

PROCESS CODE NO	PROCESS
10	Isobaric
20	Isothermal
30	Isentropic
40	Isometric
50	Polytropic
100	General
0	Exit

In the case of open system analysis, the program asks for the type of device involved. The list of the working devices along with their code numbers is contained in Table III. The code number instructs the program to select the proper equations applicable to the device. The computation runs through the equations twice. First, by using the given actual process between I and F as the end points of the process. Second, by using the isentropic process between I and S as the end points of the process. Where the values of S is determined from the value of F as F + 5. By this, the program can calculate the device efficiency or to use of which in computing other unknowns. In order to perform this operation, two loops have been used in the main program as shown in Appendix K. These loops are named MALL and MAB. Further, the program asks whether the kinetic energy change and/or potential energy change are negligible. If they are negligible, the program calls for SUBIN and stores their values as zero.

In the case of a closed system analysis, the program asks whether there is external work acting on the system such as paddle work. This input is needed to determine the total work of the system. The total work is the sum of the boundary work and the external work. If the external work does not exist, then the program calls for SUBIN to equate it to zero.

The program then asks whether the process is adiabatic or not. If it is adiabatic, then the program calls for SUBIN and sets the heat

TABLE III. The Device Code Numbers

DEVICE CODE NO	DEVICE
1	Heat Exchangers
2	Turbine
3	Nozzle
4	Compressor
5	Diffuser
6	Piston (for air-standard cycles)
7	Others

transfer terms to zero. If the process is isentropic, the program will skip this question since the heat transfer terms have already been stored as zero in the isentropic subroutine.

The next group of questions deals with the entry of data provided by the problem statements. The data entry consists of two parts. In the first part, the program requests for the values of K, c_p, c_v, R, and M. When any two out of these five constants are given, the others can be computed. If their values are not known, then '0' should be entered. Once a known value is entered, the program will call for SUBIN and store it in the proper location. The second part is to enter the rest of the data, e.g., T and P. As the data are entered each time the program will store them through SUBIN. At the end of the data entry session the program proceeds to the output section which consists of the optional step procedure and the process results.

In order to enable the users to study the effect of varying the values of some variables in an executed problem without having to re-enter other fixed data, the matrix DIX has been introduced in the main program. The function of this matrix is to store all the input data involved in the first executed process or cycle. The complete form of the matrix is DIX(J, A) = XX. Initially, DIX has been set to a large random number VIL for all values of J and A. Each time when data composed of J, XX, and A are entered, the matrix DIX records them by replacing its value from

VIL to XX for the given J and A.

When the program is directed to re-solve an executed problem with some new data, the program firstly sets all the VST's to zero and secondly, it examines the matrix DIX. Each time, DIX $\neq$ VIL, SUBIN is called to restore the previous input data. Thirdly, the program requests the new data. And finally, as soon as the new data are entered the program is executed.

9. THERMODYNAMIC CYCLES

A thermodynamic cycle is simply a sequence of processes that has identical initial and final states. The first law of thermodynamics for a cycle is,

$$\Sigma Q = \Sigma W$$

where ΣQ is the net heat, Q_{net}, of the cycle which is composed of heat input and heat output. We can express the cycle heat input, heat output, and net heat as:

$$Q_{in} = \Sigma Q \quad , \quad Q > 0 \qquad \text{(h)}$$

$$Q_{out} = \Sigma Q \quad , \quad Q < 0 \qquad \text{(i)}$$

$$Q_{net} = \Sigma Q = Q_{in} - |Q_{out}| \qquad \text{(j)}$$

Similarly, for work the following applies:

$$W_{in} = \Sigma W \quad , \quad W < 0 \qquad \text{(k)}$$

$$W_{out} = \Sigma W \quad , \quad W > 0 \qquad (\ell)$$

$$W_{net} = \Sigma W = W_{out} - |W_{in}| \qquad \text{(m)}$$

The thermal efficiency of the cycle can be determined, using the definition:

$$\eta = \frac{Q_{net}}{Q_{in}} = \frac{W_{net}}{Q_{in}} \qquad (n)$$

Similar equations can be written in terms of unit mass, unit time, and unit mass per unit time.

The approach used in the analysis of thermodynamic cycles is based on treating each process separately and in a consecutive order until all processes have been covered. Because the state data and results of each process are stored, there is no need to enter them again in the next processes. But the order of the processes should be handled with care. For example, if the initial point of the first process is state 1, and the final point is state 2; then the second process must occur between states 2 and 3 as initial and final points respectively. Furthermore, in order to complete the cyclic analysis, the final state of the last process must be the initial state of the first process. This condition is a necessary one to complete the cyclic analysis. Once this is satisfied, the program will go on to the equations applied to the cycle. From there, the program will compute and print out the cycle results. The results contain heat input, heat output, work input, work output, net work and the thermal efficiency of the cycle involved.

The technique used to carry out the cycle analysis is a part of the function of the main program. By referring to the flow chart of the main program (Appendix K), we observe that each time the program is transferred to execute a new process, the NPN increments by one. Hence, the NPN serves as a process counter. When each process has been analysed, the program checks whether F coincides to IØNE or not. As stated, F is the final state of the last process and IØNE is the initial state of the first process. If F = IØNE, the program will run through the cycle computation. But if F ≠ IØNE, the program will skip the cycle analysis.

The method used to compute the input and output quantities of heat and work for cycles is based on the equations (h), (i), (k), and (ℓ). The VST's of each term of heat and work are examined for all processes that have been executed. Next, in each variable, terms with similar signs are collected. Hence, the cycle results can be obtained. In order to see how the program achieves this, let us consider Q_{in}. In the flow diagram shown in Appendix K, SIQ is the sum of all positive values of Q. Initially, SIQ is set to zero. Then, two "DØ" loop statements, ICI and ICF are used. The function of these is to examine the status of Q terms for all processes. If the value of Q is known and it is positive, then the value will be added to SIQ. Eventually, at the end of the loops, the sum of positive Q's will be found. Therefore, according to equation (h), Q_{in} is evaluated as:

$$Q_{in} = SIQ \tag{o}$$

Similarly, other terms of heat and work can be evaluated. Then, by direct application of equations (j), (m), (n) and similar ones, the net heat, net work and the thermal efficiency of the cycle can be determined.

In the case of re-solving an executed cycle with new cycles for some variables, the program initialize all VST's and examines the matrix DIX in order to restore the input data. Before entering the new data, the program requests the initial and final states of the process to which the new values are associated. Then the program is directed to the computation routine. In order to analyse all processes involved in the cycle, the "DO" loop statement LZ is used. At the end of each process analysis, the program calls for OUTPUT in order to write out the process results. When the loop LZ ends, the program is directed to the cycle analysis where the cycle results can be obtained.

Although the program is intended to be general enough to solve a cycle consisting of any number of processes, in this work the maximum number of processes allowed has been limited to five. However, it is possible to increase this number by modifying the COMMON, REAL, INTEGER, and several other statements in the source program. On the other hand, the minimum number of processes must be three in order to form a cycle.

10. PROGRAM OUTPUT

The output of the program consists of three main parts:

A) STEP PROCEDURE

When the program completes the necessary loops of computation, it writes out all the steps which have been involved in the computation.

The method of writing the step procedure is based on examining the matrix KR(N, JE). If KR = 1, then the program writes the first equation used in the computation. Similarly, if KR = 2, it writes the second equation used. In order to write the complete list, two nested "DO" loops are used in the main program, as shown in Appendix K. The outer loop takes care of step numbers and the inner loop takes care of equation numbers.

B) PROCESS RESULTS

When the program completes the writing of the step procedure, it calls for the subroutine OUTPUT to write the output matrix according to Figure 8.

The technique used in the subroutine OUTPUT is based on the block diagram as shown in Appendix M. The subroutine examines the

	1	2	3	4	5	6
1	n	K	C_p	C_v	R	R_u
2	m	$\dot{m}$	t	M	N_m	g
3,7*	P	T	V	v	PV	Pv
4,8*	H	h	E	e	$\dot{E}$	$\dot{e}$
5,9*	U	u	$\dot{V}$	KE	$\vec{V}$	A
6,10*	S	s	V_m	PE	Z	ρ
11	W	w	$\dot{W}$	$\dot{w}$	$\Delta\dot{E}$	$\Delta\dot{e}$
12	W_f	w_f	$\dot{W}_f$	$\dot{w}_f$	ΔE	Δe
13	W_a	w_a	$\dot{W}_a$	$\dot{w}_a$	ΔH	Δh
14	Q	q	$\dot{Q}$	$\dot{q}$	ΔU	Δu
15	Q_f	q_f	$\dot{Q}_f$	$\dot{q}_f$	ΔKE	ΔPE
16	Q_a	q_a	$\dot{Q}_a$	$\dot{q}_a$	ΔS	Δs
17	ΔP	ΔT	ΔV	Δv	ΔPV	ΔPv
18	P_r	T_r	V_r	A_r	$\vec{V}_r$	ΔZ
19	W_s	w_s	$\dot{W}_s$	$\dot{w}_s$	ΔKE_s	$\vec{V}_s$
20	T_s	ΔT_s	TDS	ΔH_s	Δh_s	η

*Final state values.

Figure 8. The Output Matrix

status of each variable. If the variable value is unknown, then the program will equate the variable to BL which is a large random number that cannot be written by the specified field format. The quantity of BL is represented by " *** " on print out.

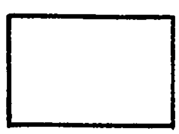
C) CYCLE RESULTS

Finally, the program checks whether a thermodynamic cycle is involved or not. The check is based on comparing the initial state of the first process to that of the final state of the last process. If they are equal, then the program will write the cycle results that contains heat input, heat output, work input, work output, net work and thermal efficiency. If they are not equal, then the program skips this result and proceeds to the next process.

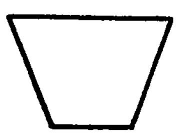
11. USING THE PROGRAM

In order to use the program to analyse thermodynamic processes or cycles, users must prepare to answer each question as it is prompted by computer on the terminal. This is done by entering proper codes along with the data provided by the problem statements. The numerical input of data is free-formatted to ease the data entry. The YES or NO input can be abbreviated as Y, or N, respectively.

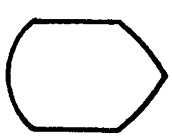
The sequence of input and output steps used in the analysis is based on the block diagram as shown in Figure 9. The following symbols are used for describing specific operations in conjunction with the block diagram:



Computer prompted question



Internal operation



Output

Start/End

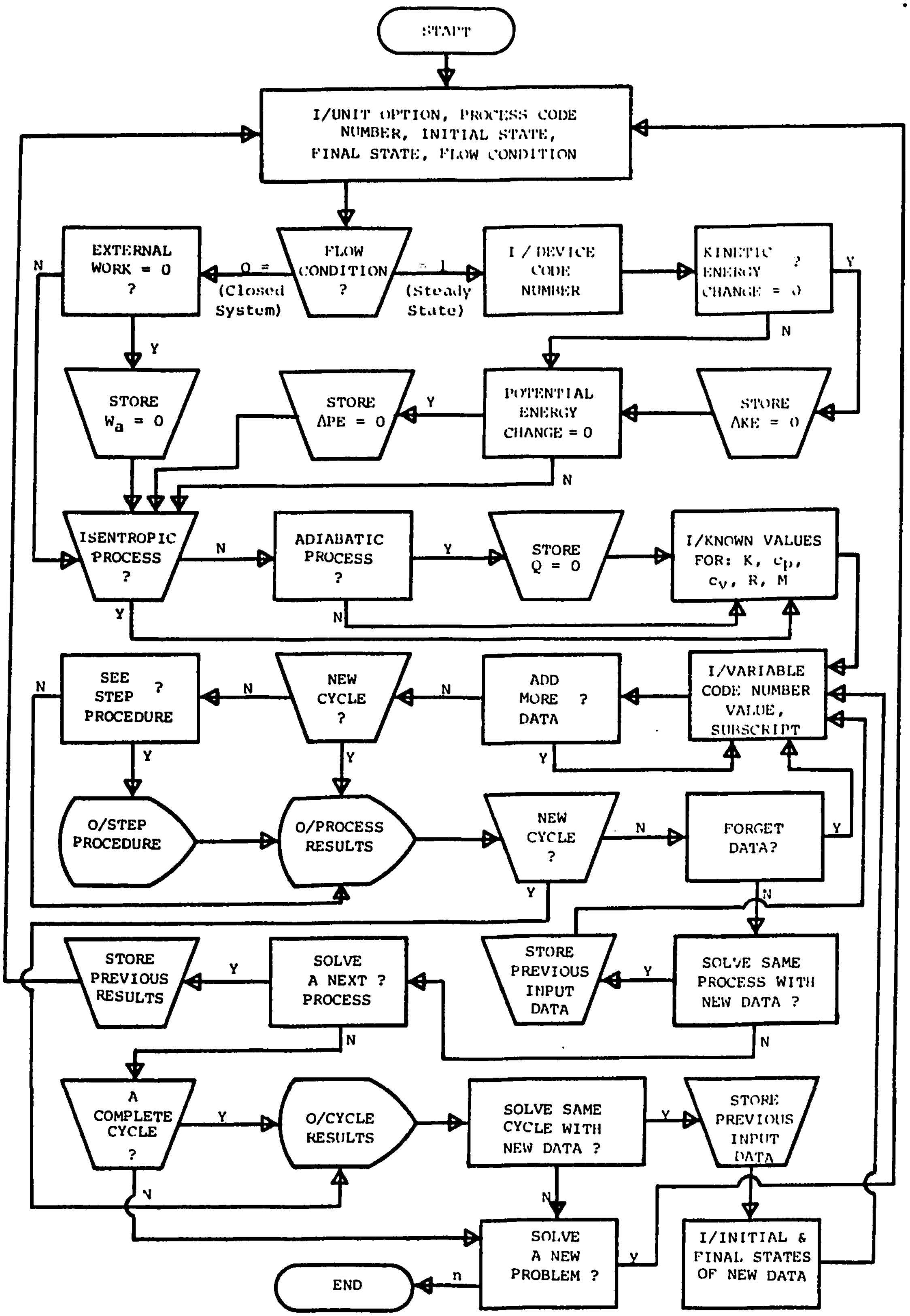


Figure 9. A Block Diagram Representation of Program Operations

The first group of data the program asks for are:

(1) UNIT

The user should refer to Table IV to select the appropriate unit code number. Appendix A contains input variables with proper units.

(2) PROCESS CODE NUMBER

The user should refer to Table II which contains the processes with their corresponding code numbers.

(3) STATES

The user should enter the numbers of initial state and final state of the process, e.g., 1 and 2, respectively. To continue the next process in a cyclic problem, 2 and 3 should be entered. This carries forth until it is back to 1 again.

(4) FLOW CONDITION

The user should refer to Table V for the code of flow conditions. If it is a steady flow problem, the next question requires the code

TABLE IV. Unit Code Number

Code No.	Description
1	Metric (S.I.) Units
2	English Engineering Units

TABLE V. System Code Numbers

Code No.	Description
0	Closed System "Non-Flow System"
1	Open System "Steady state-Steady flow System"

number of the thermodynamic device involved in the problem.

The user should refer to Table III for the device code number.

The playback of the input data is carried out after the completion of the answers to the second question. If the answers are correct, type in YES, otherwise NO.

If it is a non-flow problem, the above question on devices will be skipped.

Then, the question on the subscript for isentropic state will be prompted. The answer is given by:

Number of the final state + 5

For example, if the final state is 2, the subscript for isentropic state will be 7.

For non-flow problems, the following two questions will be prompted consecutively:

" IS IT AN ADIABATIC PROCESS?"

" IS THERE AN EXTERNAL WORK TERM?"

The answer for each question is either YES or NO.

For steady-flow problems the next three questions are asked:

" IS IT AN ADIABATIC PROCESS?"

" IS THERE A KINETIC ENERGY CHANGE?"

" IS THERE A POTENTIAL ENERGY CHANGE?"

Proper answer is YES or NO.

If it is an isentropic process, the first question:

" IS IT AN ADIABATIC PROCESS?"

will be skipped.

For either flow condition, three pertinent variables $\overline{R}$, g, and g_c, are provided in both S.I. and English units. Further, the program seeks any two known values among K, c_p, c_v, R or M. Enter "0" for unknowns.

From here on, values of other variables given by the problem should be provided as the following statement is:

" NOW, PLEASE ENTER THE REST OF THE DATA
OR THE NEW VALUES IN THE FOLLOWING ORDER:
VARIABLE CODE NUMBER, VALUE, AND SUBSCRIPT."

If no data entry, answer 0, 0, 0. In this case, the results will be given immediately. Normally, data are entered at this point.

For data entry, Appendix A should be referred to closely. As examples, to enter the data of

A. "..... final volume becomes 5.2 ft^3....."

one should enter

4 5.2 2

In which: 4 is the code number for volume

5.2 is the value of the volume

2 is the second state.

B. " .....during the process, the heat dissipated is 12.8 KJ/Kg....."

One should enter

21 -12.8 2

In which 21 is the code number for q

-12.8 is the value of q, and the minus sign indicates the direction of q.

2 represents the process from state 1 to state 2.

The inputs are played back for verification after they have been entered each time.

To provide a chance for completing the data entry, the following question is asked:

" DO YOU WANT TO ADD OR CHANGE DATA?"

If a NO answer is sensed, the users will be prompted with the question:

" WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE?"

A YES answer will display all steps involved in the computation. Every equation encountered in the solution, will be included in the steps. Therefore, some steps seem irrelevant to the user, especially those unrelated to the information required by a specific problem. However, the sequence of steps as listed provides a means for evaluating the logic involved in the solution routine for all non "***" results presented in the output matrix in Figure 8. An option is provided for those who answer NO to by-pass the listing if they so desire. The "***" results represent those variables which have not been computed.

Final results according to the output matrix are now displayed. Should the user forget additional data, do not worry, all he has to do is to enter YES when he is asked,

" DID YOU FORGET TO ENTER OTHER DATA?"

Of course, he can now enter those data which were previously left out. A new output matrix will be immediately displayed at the end of data entry. At this stage, even if he does not have more data, he is given an opportunity to see the results again on the terminal screen.

In order to enable the user to study the effect of varying the values of some variables, the following question is asked:

"WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
NEW VALUES FOR SOME OF THE VARIABLES?"

If a YES answer is sensed, the computer prompts:

" NOW, PLEASE ENTER THE REST OF THE DATA OR THE
NEW VALUES IN THE FOLLOWING ORDER:
VARIABLE CODE NUMBER, VALUE, AND SUBSCRIPT."

By this question, the user can enter the new values which will replace the old ones. As soon as the new data are entered, a new output matrix for the new set of data will be displayed A NO answer will direct the computer to the next question.

Now, in order to help the computer to decide whether the job is finished or not, the following question is prompted:

" WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED TO SOLVE THE NEXT PROCESS?"

A NO answer will bring the user back to the beginning of the solution while the program restarts itself. This concludes the solution of a process. A YES answer will also direct the user to the beginning of the solution routine but with the last results stored in computer memory. This facilitates the solution of thermodynamic cycles which contain several processes.

In a cycle analysis, a result containing heat input, heat output, work input, work output, net work and thermal efficiency will be provided.

Of course, at this state where the input data of the cycle are stored in the computer memory, the user can solve the same cycle with new values for some variables as many times as he wishes by answering the following questions:

" WOULD YOU LIKE TO SOLVE THE SAME CYCLE WITH NEW VALUES FOR SOME OF THE VARIABLES?"

A YES answer will lead the user back to the data entry session for inputting new data. Before entering the new data, the following question is prompted in order to help the computer to replace the old data with the new values:

" PLEASE ENTER THE INITIAL AND THE FINAL STATES OF THE PROCESS WITH WHICH THE NEW VALUES ARE ASSOCIATED."

For an example, if the user wants to enter a new value for η_3, the user should enter

3 4

In which 3 and 4 are the initial and final states, respectively, of the process with which η_3 is associated. Then the user can enter the data of η_3 as stated before.

After the completion of the new data entry, the computer displays sequentially the output matrices of all the processes involved in the cycle in addition to the cycle results.

At the end of the session, the user can exit the program by entering NO to the question:

" WOULD YOU LIKE TO SOLVE A NEW PROBLEM?"

12. ILLUSTRATIVE EXAMPLES

A group of solved examples are presented in this chapter to illustrate the computer-assisted technique. These examples include thermodynamic problems in closed system, open system, as well as in thermodynamic cycles. For each example, a problem statement is given first, then followed by the computer print-outs. These examples will serve to describe the procedure involved in the data entry, and will demonstrate the use of the program and its important features.

In order to facilitate the input data entry requested by the computer, input tables as shown in Figure 10 are prepared. Prior to using the program, users are recommended to fill those tables with data provided by the problem statements. Each process calls for a set of these tables. Therefore, for problems involving a cycle, the number of sets of those tables to be filled out is equal to the number of processes involved. Using these tables will make the data input easier, minimize unnecessary mistakes encountered in the data entry session and help the user develop a methodical approach to the solution of thermodynamic problems.

The first example taken from Wark [12] demonstrates the use of the program for a closed system with a constant pressure process. Also it demonstrates the capability of the program in studying the effects of varying the values of certain parameters.

	Unit	Process	Initial State	Final State	Flow Type	Device
DESCRIPTION						
CODE NUMBER						

	Yes	No
IS IT ADIABATIC?		
IS THERE EXTERNAL WORK?		
IS THERE KINETIC ENERGY CHANGE?		
IS THERE POTENTIAL ENERGY CHANGE?		

	K	C_p	C_v	R	M
VALUE					

Data	Variable Code No	Value	Subscript

Figure 10. The Input Data Tables

EXAMPLE 1

Nitrogen gas at 1 bar and 27°C occupies an initial volume of 45 liters in a piston-cylinder device. A paddle-wheel within the cylinder is turned until 9500 newton-meters of energy have been added to the gas (neglect mass of paddle-wheel). If the process is adiabatic and at constant pressure, determine:

a) The final temperature of the gas.

b) The entropy change of the gas.

c) The final temperature assuming the pressure is 2 bars.

In order to solve this problem by using the computer program, the quantities are first converted to S.I.units according to that given in Appendix A. Then these data along with their corresponding code numbers are tabulated as shown in Figure 11. Note that the data of C_p and C_v are taken from the gas tables at the initial temperature.

After preparing these tables for input data, the following procedure becomes simple and straightforward. The user needs only to enter these data on terminal whenever a question is prompted by the computer.

A print-out of this example as shown in Figure 12 illustrates the way the input data are entered. The numerical quantities are free

	Unit	*Process*	*Initial State*	*Final State*	*Flow Type*	*Device*
DESCRIPTION	SI	ISOBARIC	I	F	Closed	Piston-Cylinder
CODE NUMBER	1	10	1	2	0	

	Yes	*No*
IS IT ADIABATIC?	√	
IS THERE EXTERNAL WORK?	√	
IS THERE KINETIC ENERGY CHANGE?		√
IS THERE POTENTIAL ENERGY CHANGE?		√

	K	C_p	C_v	*R*	*M*
VALUE		1.039	0.742		

Data	*Variable Code No*	*Value*	*Subscript*
$P_1 = 100$	1	100	1
$T_1 = 300$	2	300	1
$V_1 = 0.045$	4	0.045	1
$W_a = -9.5$	71	-9.5	2
$P_1 = 200$	1	200	1

Figure 11. The Input Data Tables for Example 1

```
*****************************************************************************
    THIS IS A GENERAL PROGRAM TO AID THE SOLUTION OF THERMODYNAMIC PROCESSES
    AND CYCLES BASED ON IDEAL GAS RELATIONSHIPS
*****************************************************************************

   PLEASE ENTER : -
  -----------------
  UNITS OPTION:-  1  FOR METRIC UNITS , 2  FOR ENGLISH UNITS
  PROCESS CODE NUMBER :-
          ISOBARIC    PROCESS   10
          ISOTHERMAL PROCESS   20
          ISENTROPIC PROCESS   30
          ISOMETRIC  PROCESS   40
          POLYTROPIC PROCESS   50
          GENERAL    PROCESS  100
          E  X  I  T            0
  INITIAL STATE OF THE PROCESS ,
  FINAL STATE OF THE PROCESS : AND
  FLOW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NON-FLOW

          1          10          1          2          0

     YOU ENTERED THE FOLLOWING DATA :-
-------------------------------------------------
   UNITS  OPTION        =  1
   PROCESS CODE NUMBER = 10
   INITIAL STATE        =  1
   FINAL STATE          =  2
   FLOW CONDITION       =  0
-------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NO

YES

  SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =     7

-----------------------------------------------------------------------------
      IS IT AN ADIABATIC PROCESS ?
 **  PLEASE ENTER EITHER   YES  OR  NO
-----------------------------------------------------------------------------
YES

-----------------------------------------------------------------------------
      IS THERE AN EXTERNAL WORK TERM ?
 **  PLEASE ENTER EITHER   YES  OR  NO
-----------------------------------------------------------------------------
YES

*****************************************************************************
 THE VALUES OF THE FOLLOWING CONSTANTS ARE STORED FOR YOU :-
 RU = 8.3150     SI UNIT        RU = 1545    ENGLISH UNIT
 G  = 9.80       SI UNIT        G  = 32.2    ENGLISH UNIT
 GC = 1.0        SI UNIT        GC = 32.2    ENGLISH UNIT
IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PROPER VALUE
*****************************************************************************
    PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNOWN ENTER  0

 .0

    PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0

 1.03899956

    PLEASE ENTER THE VALUE OF (25):CV , IF IT IS  UNKNOWN ENTER  0

 .741999984
```

Figure 12. Computer Print-out of Example 1

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          1   100.000000              1


     THE DATA YOU ENTERED ARE :-
-------------------------------------------------
   VARIABLE CODE NUMBER =      1
   VALUE                =   100.00000
   SUBSCRIPT            =      1
-------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

YES


     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

YES


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          2   300.000000              1


-------------------------------------------------
   VARIABLE CODE NUMBER =      2
   VALUE                =   300.00000
   SUBSCRIPT            =      1
-------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

YES


     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

YES


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          4   .449999988              1


     THE DATA YOU ENTERED ARE :-
-------------------------------------------------
   VARIABLE CODE NUMBER =      4
   VALUE                =   0.45000
   SUBSCRIPT            =      1
-------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

NO


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
```

Figure 12. (Continued)

```
     4    .45C000C18E-01            1

     THE DATA YOU ENTEFED ARF :-
--------------------------------------------------
   VARIABLE CODE NUMBEF =      4
   VAI UE               =      0.045C0
   SUBSCRIPT            =      1
--------------------------------------------------
***IF OK . TYPE IN YES. IF NCT TYPE IN NO

Y

    DO YOU WANT TO ACC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NC

N

    WOULD YOU LIKE TO SEE THE SCLUTICN PROCEDURE ?
***  TYPE IN EITHER  YES  CR  NC

N


                        *****  R E S U L T S  *****

PROCESS # = 1     PROCESS CODE # = 10     INITIAL STATE = 1     FINAL STATE = 2
--------------------------------------------------------------------------------
 1)        C.0          1.4003       1.0390       0.7420       0.2970       8.31
 2)     0.0505 ************ ************       27.5967 ************ **********
 3)   10C.0000    300.0000       0.0450       0.8910       4.5000      89.09
 4)    15.7424    311.6997      11.2424     222.60CC ************ **********
 5)    11.2424    222.6000 ************ ************ ************ **********
 6) ************ ************       0.0318 ************ ************       1.12
 7)   100.0000 ************ ************ ************ ************ **********
 8) ************ ************ ************ ************ ************ **********
 9) ************ ************ ************ ************ ************ **********
10) ************ ************ ************ ************ ************ **********
11) ************ ************ ************ ************ ************ **********
12) ************ ************ ************ ************ ************ **********
13) ************ ************ ************ ************ ************ **********
14)        C.0          0.0          C.0          0.E   ************ **********
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************ ************ **********
17)        0.0   ************ ************ ************ ************ **********
18)     1.0000 ************ ************ ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********


    DID YOU FORGET TO ENTER CTHER DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y
```

Figure 12. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

        71  -9.50000000                 2

     THE DATA YOU ENTERED ARE :-
------------------------------------------------
   VARIABLE CODE NUMBER =     71
   VALUE                =     -9.50000
   SUBSCRIPT            =      2
------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

N

    WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
***  TYPE IN EITHER  YES  OR  NO

Y
                 STEP NUMBER    1 . USE EQUATION NUMBER 1001
                 STEP NUMBER    2 . USE EQUATION NUMBER 1002
                 STEP NUMBER    3 . USE EQUATION NUMBER 1003
                 STEP NUMBER    4 . USE EQUATION NUMBER 1004
                 STEP NUMBER    5 . USE EQUATION NUMBER 1021
                 STEP NUMBER    6 . USE EQUATION NUMBER   52
                 STEP NUMBER    7 . USE EQUATION NUMBER  169
                 STEP NUMBER    8 . USE EQUATION NUMBER  281
                 STEP NUMBER    9 . USE EQUATION NUMBER  284
                 STEP NUMBER   10 . USE EQUATION NUMBER  293
                 STEP NUMBER   11 . USE EQUATION NUMBER  311
                 STEP NUMBER   12 . USE EQUATION NUMBER  319
                 STEP NUMBER   13 . USE EQUATION NUMBER  405
                 STEP NUMBER   14 . USE EQUATION NUMBER  409
                 STEP NUMBER   15 . USE EQUATION NUMBER    2
                 STEP NUMBER   16 . USE EQUATION NUMBER    5
                 STEP NUMBER   17 . USE EQUATION NUMBER   11
                 STEP NUMBER   18 . USE EQUATION NUMBER   31
                 STEP NUMBER   19 . USE EQUATION NUMBER   34
                 STEP NUMBER   20 . USE EQUATION NUMBER   50
                 STEP NUMBER   21 . USE EQUATION NUMBER   69
                 STEP NUMBER   22 . USE EQUATION NUMBER   84
                 STEP NUMBER   23 . USE EQUATION NUMBER  117
                 STEP NUMBER   24 . USE EQUATION NUMBER  120
                 STEP NUMBER   25 . USE EQUATION NUMBER  379
                 STEP NUMBER   26 . USE EQUATION NUMBER  385
                 STEP NUMBER   27 . USE EQUATION NUMBER  417
                 STEP NUMBER   28 . USE EQUATION NUMBER   64
                 STEP NUMBER   29 . USE EQUATION NUMBER   73
                 STEP NUMBER   30 . USE EQUATION NUMBER   76
                 STEP NUMBER   31 . USE EQUATION NUMBER   79
                 STEP NUMBER   32 . USE EQUATION NUMBER   88
                 STEP NUMBER   33 . USE EQUATION NUMBER   91
                 STEP NUMBER   34 . USE EQUATION NUMBER  118
                 STEP NUMBER   35 . USE EQUATION NUMBER  119
                 STEP NUMBER   36 . USE EQUATION NUMBER  121
                 STEP NUMBER   37 . USE EQUATION NUMBER  122
                 STEP NUMBER   38 . USE EQUATION NUMBER  256
                 STEP NUMBER   39 . USE EQUATION NUMBER  259
                 STEP NUMBER   40 . USE EQUATION NUMBER  340
                 STEP NUMBER   41 . USE EQUATION NUMBER  352
                 STEP NUMBER   42 . USE EQUATION NUMBER  358
                 STEP NUMBER   43 . USE EQUATION NUMBER  361
                 STEP NUMBER   44 . USE EQUATION NUMBER  364
                 STEP NUMBER   45 . USE EQUATION NUMBER  366
                 STEP NUMBER   46 . USE EQUATION NUMBER  369
                 STEP NUMBER   47 . USE EQUATION NUMBER  408
                 STEP NUMBER   48 . USE EQUATION NUMBER 1007
                 STEP NUMBER   49 . USE EQUATION NUMBER 1010
                 STEP NUMBER   50 . USE EQUATION NUMBER   24
                 STEP NUMBER   51 . USE EQUATION NUMBER   37
                 STEP NUMBER   52 . USE EQUATION NUMBER   60
```

Figure 12. (Continued)

```
STEP NUMBER   53 . USE EQUATION NUMBER  170
STEP NUMBER   54 . USE EQUATION NUMBER  180
STEP NUMBER   55 . USE EQUATION NUMBER  181
STEP NUMBER   56 . USE EQUATION NUMBER  298
STEP NUMBER   57 . USE EQUATION NUMBER  430
STEP NUMBER   58 . USE EQUATION NUMBER  433
STEP NUMBER   59 . USE EQUATION NUMBER  436
STEP NUMBER   60 . USE EQUATION NUMBER  439
STEP NUMBER   61 . USE EQUATION NUMBER  446
STEP NUMBER   62 . USE EQUATION NUMBER   13
STEP NUMBER   63 . USE EQUATION NUMBER  105
STEP NUMBER   64 . USE EQUATION NUMBER  184


                  ***** R E S U L T S *****

PROCESS # = 1     PROCESS CODE # = 10     INITIAL STATE = 1     FINAL STATE = 2
----------------------------------------------------------------------------------
 1)        0.0       1.4003       1.0390       0.7420       0.2970        8.31

 2)     0.0505 ************ ************      27.5567 ************ **********

 3)   100.0000     200.0000       0.0450       0.6910       4.5000       89.09

 4)    15.7424     311.6997      11.2424     222.6000 ************ **********

 5)    11.2424     222.6000 ************ ************ ************ **********

 6) ************ ************     0.0318 ************ ************        1.12

 7)   100.0000     481.0388       0.0722       1.4267       7.2156      142.86

 8)    25.2424     459.7993      18.0268     356.9309 ************ **********

 9)    18.0268     356.9309 ************ ************ ************ **********

10) ************ ************     0.0510 ************ ************        0.69

11)    -6.7844    -134.3312 ************ ************ ************ **********

12)     2.7156      53.7686 ************ ************       6.7844      134.33

13)    -9.5000    -188.0997 ************ ************       9.5000      188.09

14)        0.0          0.0          0.0          0.0       6.7844      134.33

15) ************ ************ ************ ************ ************ **********

16) ************ ************ ************ ************       0.0248        0.49

17)        0.0     181.0393       0.0272       0.5377       2.7156       53.76

18)     1.0000       1.6035       1.6035 ************ ************ **********

19) ************ ************ ************ ************ ************ **********

20) ************ ************ ************ ************ ************ **********


    DID YOU FORGET TO ENTER OTHER DATA ?
***   TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
***  TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
***  TYPE IN EITHER   YES   OR   NO

YES
```

Figure 12. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          1   200.000000              1

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =      1
   VALUE                =   200.00000
   SUBSCRIPT            =      1
--------------------------------------------------
***IF OK , TYPE IN YES. IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

N

     WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
***  TYPE IN EITHER  YES  OR  NO

N

                   *****  R E S U L T S  *****

PROCESS # = 1     PROCESS CODE # = 10     INITIAL STATE = 1     FINAL STATE = 2
----------------------------------------------------------------------------------
 1)      C.0          1.4003       1.0390       0.7420       C.2570       8.31
 2)      0.1010 ************ ************      27.9567 ************ **********
 3)    200.0000     300.0000       C.0450       0.4455       9.0000      89.09
 4)     31.4848     311.6997      22.4849     222.6000 ************ **********
 5)     22.4849     222.6000 ************ ************ ************ **********
 6) ************ ************       C.0159 ************ ************       2.24
 7)    200.0000     390.5195       C.0586       0.5799      11.7156     115.98
 8)     40.9848     405.7495      29.2693     289.7654 ************ **********
 9)     29.2693     289.7654 ************ ************ ************ **********
10) ************ ************       C.0207 ************ ************       1.72
11)     -6.7844     -67.1656 ************ ************ ************ **********
12)      2.7156      26.8843 ************ ************       6.7844      67.16
13)     -9.5000     -94.0459 ************ ************       9.5000      94.04
14)      C.0          0.0          C.0          0.C          6.7844      67.16
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************       C.C271       0.27
17)      C.0         50.5157       0.0136       0.1344       2.7156      26.88
18)      1.0000       1.3017       1.3017 ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********
```

Figure 12. (Continued)

```
     DID YOU FORGET TO ENTER OTHER DATA ?
 ***   TYPE IN EITHER  YES  OR  NO

N

     WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
 ***  TYPE  IN EITHER  YES  OR  NO

N

    WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
 ***  TYPE  IN EITHER   YES   OR   NO

N

     WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PROCESS  ?
 ***  TYPE  IN EITHER    YES   OR   NO

N
##############################################################################
  WOULD YOU LIKE TO SOLVE A NEW PROBLEM ?
 *** TYPE IN EITHER    YES   OR   NO
##############################################################################

YES
```

Figure 12. (Continued)

formatted, while YES or NO inputs can be abbreviated as Y or N, respectively. Also it shows that the program has given the user a chance to re-enter the correct value of V (volume) 0.045, instead of 0.45. Obviously, in the first output matrix, the user forgot to enter the data of W_a. But the computer has made possible for him to enter this data when he is asked whether he has forgotten to enter other data. When the user has completed the data entry session, he may request for the step procedure involved in the solution. At this time, the computer displays immediately the procedure along with an output matrix. Of course, the last output matrix contains all required results of part (a) and (b). By comparing this matrix (Figure 12) with the matrix as shown in Figure 8 we find the results directly on the computer output:

(a) The final temperature = 481.0388°R

(b) The entropy change = 0.4906 KJ/Kg.°R

To solve for the part (c), normally it would require to solving the problem from the beginning with the new value of P. To do this, however, by using the program is rather simple. One needs just to enter the new value of P when the computer prompts for it. When the P value has been entered, the computer displayed immediately the output matrix for the new set of data. From this matrix the required result of part (c) is found as:

(c) The final temperature = 390.5195°R

The second example also taken from Wark [12] illustrates the use of the program for a constant volume (isometric) process.

EXAMPLE 2

One-tenth pound of an ideal gas is enclosed in a rigid tank at a pressure of 18 psia and a temperature of 80°F. A paddle-wheel with the tank does 390 ft-lb_f of work on the substance, and 0.77 Btu of heat is added at the same time. If the temperature of the gas, which has a molecular mass of 48, rises 80°F during the process, compute the average specific heat C_v for the gas.

The input data have been converted to the appropriate units and then tabulated as shown in Figure 13. The output of the program for this example is shown in Figure 14.

The required result of the average specific heat appearing in position (1, 4) in the output matrix is

$$91.4633 \ \frac{\text{ft-lb}}{\text{lbm-°R}}$$

	Unit	Process	Initial State	Final State	Flow Type	Device
DESCRIPTION	English	Isometric	I	F	Closed	Tank
CODE NUMBER	2	40	1	2	0	

	Yes	No
IS IT ADIABATIC?		√
IS THERE EXTERNAL WORK?	√	
IS THERE KINETIC ENERGY CHANGE?		√
IS THERE POTENTIAL ENERGY CHANGE?		√

	K	C_p	C_v	R	M
VALUE					48

Data	Variable Code No	Value	Subscript
$m_1 = 0.1$	3	0.1	1
$P_1 = 2592$	1	2592.0	1
$T_1 = 540$	2	540.0	1
$W_a = -390$	71	-390.0	2
$Q = 599.2$	20	599.2	2
$\Delta T = 80$	38	80.0	2

Figure 13. The Input Data Tables for Example 2

```
*******************************************************************************
    THIS IS A GENFRAL PROGRAM TO AIC THE SOLUTION OF THERMODYNAMIC PROCESSES
    AND CYCLES BASEC ON IDEAL GAS RELATIONSHIPS
*******************************************************************************


   PLEASE ENTER : -
  ------------------
  UNITS OPTION:-  1  FCR METRIC UNITS , 2  FOR ENGLISH UNITS
  PROCESS CODE NUMBER :-
          ISOBARIC    PROCESS   10
          ISOTHERMAL  PROCESS   20
          ISENTROPIC  PROCESS   30
          ISOMETRIC   PROCESS   40
          POLYTROPIC  PROCESS   50
          GENERAL     PROCESS  100
          E  X  I  T             0
  INITIAL STATE OF THE PROCESS ,
  FINAL STATE OF THE PROCESS ; AND
  FLOW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NON-FLOW

        2          40            1            2            0


     YOU ENTERED THE FOLLOWING DATA :-
 ------------------------------------------------
   UNITS  OPTION        =   2
   PROCESS CODE NUMBER =  40
   INITIAL STATE        =   1
   FINAL STATE          =   2
   FLOW CONDITION       =   0
 ------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

  SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =     7

-------------------------------------------------------------------------------
      IS IT AN ADIABATIC PROCESS ?
 **  PLEASE ENTER EITHER   YES  OR  NO
-------------------------------------------------------------------------------
N

-------------------------------------------------------------------------------
      IS THERE AN EXTERNAL WORK TERM ?
 **  PLEASE ENTER EITHER   YES  OR  NO
-------------------------------------------------------------------------------
Y

###############################################################################
 THE VALUES OF THE FOLLOWING CONSTANTS ARE STORED FOR YOU :-
  RU = 8.3150      SI UNIT        RU = 1545    ENGLISH UNIT
  G  = 9.80        SI UNIT        G  = 32.2    ENGLISH UNIT
  GC = 1.0         SI UNIT        GC = 32.2    ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PROPER VALUE
###############################################################################

    PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNOWN ENTER  0

  .0

    PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0

  .0

    PLEASE ENTER THE VALUE OF (25):CV , IF IT IS  UNKNOWN ENTER  0

  .0

    PLEASE ENTER THE VALUE OF (28):MW , IF IT IS  UNKNOWN ENTER  0

  48.0000000

    PLEASE ENTER THE VALUE OF (22):R  , IF IT IS  UNKNOWN ENTER  0

  .0
```

Figure 14. Computer Print-out of Example 2

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST CF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORCER  :-
    VARIABLE CODE NUMBER   ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NC DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          3   .1C0000C24              1

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CCDE NUMBER =      3
   VALUE                =      0.10000
   SUBSCRIPT            =      1
--------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TO ACC OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  CR  NC

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FCLLCWING CRCER  :-
    VARIABLE CODE NUMBER   ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NC CATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          1   2592.CCCCO              1

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =      1
   VALUE                =  2592.COOCC
   SUBSCRIPT            =      1
--------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TO ACC OR CHANGE CATA ?
 ***  TYPE IN EITHER  YES  CR  NC

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST CF THE CATA OR THE NEW VALUES
    IN THE FCLLCWING CRCER  :-
    VARIABLE CODE NUMBER   ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NC DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          2   540.COOCCO              1

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =      2
   VALUE                =    540.00000
   SUBSCRIPT            =      1
--------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y
```

Figure 14. (Continued)

```
    DO YOU WANT TO ACC OR CHANCE DATA ?
 ***  TYPE IN EITHER  YES  CR  NC

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FCLLCWING CRCER  :-
    VARIABLE CODE NUMPER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


        71  -39C.CCOCOO                2

    THE DATA YCU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =    71
   VALUE                =  -390.COOCC
   SUBSCRIPT            =     2
--------------------------------------------------
***IF OK , TYPE IN YES, IF NCT TYPE IN NO


Y


    DO YOU WANT TC ADC OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  CR  NO

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST CF THE DATA OR THE NEW VALUES
    IN THE FCLLOWING CRCER  :-
    VARIABLE CODE NUMPER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


        20   5S5.199S51                2

    THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =    20
   VALUE                =   599.19995
   SUBSCRIPT            =     2
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADC OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  CR  NC

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALULS
    IN THE FCLLCWING CRCER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


        3E   8C.CCOOCCO                2
```

Figure 14.   (Continued)

```
     THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =    38
   VALUE                =    80.00000
   SUBSCRIPT            -     2
---------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

    DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

N

    WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
 ***  TYPE IN EITHER  YES  OR  NO

N
```

***** R E S U L T S *****

PROCESS # = 1   PROCESS CODE # = 40   INITIAL STATE = 1   FINAL STATE = 2

1)	************	1.3519	123.6507	51.4633	32.1675	1545.00
2)	0.1000	************	************	48.0000	************	**********
3)	2592.0000	540.0000	0.6706	6.7057	1738.1250	17381.24
4)	6677.1367	66771.3750	4939.0156	49390.1562	************	**********
5)	4939.0156	49390.1562	************	************	************	**********
6)	************	************	0.1357	************	************	0.14
7)	2975.9985	620.0000	0.6706	6.7057	1995.6238	19956.23
8)	7666.3437	76663.4375	5670.7227	56707.2187	************	**********
9)	5670.7227	56707.2187	************	************	************	**********
10)	************	************	0.1357	************	************	0.14
11)	-390.0000	-3859.9590	************	************	************	**********
12)	0.0	0.0	0.0	0.0	989.2000	9891.99
13)	-390.0000	-3859.9590	************	************	989.2000	9891.99
14)	595.2000	5551.9961	************	************	731.7012	7317.00
15)	************	************	************	************	************	**********
16)	************	************	************	************	1.2636	12.63
17)	383.9985	80.0000	0.0	0.0	257.4588	2574.58
18)	1.1481	1.1481	1.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

```
    DID YOU FORGET TO ENTER OTHER DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

N
```

Figure 14. (Continued)

```
     WOULD YCU LIKE TO SEE THE RESULTS AGAIN ?
 ***  TYPE IN EITHER  YES  OR  NC

N


    WOULD YOU LIKE TO SCLVE THE SAME PROCESS WITH
    NEW VALLES FCR SCME OF THE VARIABLES  ?
 ***  TYPE IN EITHER   YES   OR   NC

N


     WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PRCCESS  ?
 ***  TYPE IN EITHER    YES   OR   NC

N

################################################################################
  WOULD YOU LIKE TC SCLVE A NEW PRCBLEM ?
 *** TYPE IN EITHER    YES   OR   NC
################################################################################

Y
```

Figure 14. (Continued)

The third example taken from Huang [11] illustrates the use of the program for an open system involving a nozzle.

EXAMPLE 3

The nozzle of a turbojet engine received gas from the turbine exhaust at 1.8 bars and 707°C, with a velocity of 70 m/s. The nozzle expands the gas adiabatically to a pressure of 0.7 bar. Determine the discharge velocity if the nozzle efficiency is 90 percent, and the mass flow rate if the outlet area is 75 cm^2.

The input data of this example are tabulated as shown in Figure 15 after they have been converted to the proper units. The print-out of the computer for this example is shown in Figure 16. From the output matrix we found the required results as:

Discharge velocity $\vec{V}_2$ = 655.5593 m/s

Mass flow rate $\dot{m}$ = 15.1237 Kg/s

	Unit	Process	Initial State	Final State	Flow Type	Device
DESCRIPTION	SI	General	I	F	Open	Nozzle
CODE NUMBER	1	100	1	2	1	3

	Yes	No
IS IT ADIABATIC?	✓	
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?	✓	
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	R	M
VALUE		1.338	1.136		

Data	Variable Code No	Value	Subscript
$P_1 = 180$	1	180	1
$T_1 = 980$	2	980	1
$\vec{V}_1 = 70$	30	70	1
$P_2 = 70$	1	70	2
$\eta = 0.90$	99	0.90	1
$A_2 = 0.075$	76	0.075	2

Figure 15. The Input Data Tables for Example 3

```
*******************************************************************************
    THIS IS A GENERAL PROGRAM TO AID THE SOLUTION OF THERMODYNAMIC PROCESSES
    AND CYCLES BASED ON IDEAL GAS RELATIONSHIPS
*******************************************************************************


    PLEASE ENTER : -
   -----------------
   UNITS OPTION:-  1  FOR METRIC UNITS , 2  FOR ENGLISH UNITS
   PROCESS CODE NUMBER :-
           ISOBARIC    PROCESS   10
           ISOTHERMAL  PROCESS   20
           ISENTROPIC  PROCESS   30
           ISOMETRIC   PROCESS   40
           POLYTROPIC  PROCESS   50
           GENERAL     PROCESS  100
           E  X  I  T             0
   INITIAL STATE OF THE PROCESS ,
   FINAL STATE OF THE PROCESS : AND
   FLOW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NON-FLOW

           1         100            1           2           1

    PLEASE ENTER THE DEVICE CODE NUMBER :
 ------------------------------------------
  HEAT EXCHANGER: 1  , TURBINE: 2  , NOZZLE: 3  ,  COMPRESSOR: 4  , DIFFUSER: 5
   PISTON: 6   , OTHERS: 7

           3


     YOU ENTERED THE FOLLOWING DATA :-
 ---------------------------------------------------
   UNITS  OPTION           =   1
   PROCESS CODE NUMBER     = 100
   INITIAL STATE           =   1
   FINAL STATE             =   2
   FLOW CONDITION          =   1
   DEVICE CODE NUMBER      =   3
 ---------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

  SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =     7

 ------------------------------------------------------------------------------
       IS IT AN ADIABATIC PROCESS ?
 **  PLEASE ENTER EITHER   YES  OR  NO
 ------------------------------------------------------------------------------
Y

 ------------------------------------------------------------------------------
    IS THERE A KINETIC ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  OR  NO
 ------------------------------------------------------------------------------
Y

 ------------------------------------------------------------------------------
    IS THERE A POTENTIAL ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  OR  NO
 ------------------------------------------------------------------------------
N

*******************************************************************************
 THE VALUES OF THE FOLLOWING CONSTANTS ARE STORED FOR YOU :-
  RU = 8.3150    SI UNIT        RU = 1545   ENGLISH UNIT
  G  = 9.80      SI UNIT        G  = 32.2   ENGLISH UNIT
  GC = 1.0       SI UNIT        GC = 32.2   ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PROPER VALUE
*******************************************************************************

    PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNOWN ENTER  0

  1.33800030

    PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0

  1.13599968
```

Figure 16. Computer Print-out of Example 3

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  O
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          1   180.000C00              1

     THE CATA YOU ENTERED ARE :-
----------------------------------------------
   VARIABLE CODE NUMBER =      1
   VALUE                =    180.00000
   SUBSCRIPT            =      1
----------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TO ACC OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST CF THE DATA OR THE NEW VALUES
    IN THE FCLLOWING CRCER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NC DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          2   980.CC0C00              1

     THE DATA YCL ENTERED ARE :-
----------------------------------------------
   VARIABLE CODE NUMBER =      2
   VALUE                =    980.0000C
   SUBSCRIPT            =      1
----------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TO ACC OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  CR  NC

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FCLLOWING OFCER  :-
    VARIABLE CCDE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO CATA AVAILABLE , FLEASE ENETER : C  C  O
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          30   7C.CCCCCCO              1

     THE DATA YOU ENTERED ARE :-
----------------------------------------------
   VARIABLE CODE NUMBER =     30
   VALUE                =     70.CCOCC
   SUBSCRIPT            =      1
----------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y
```

Figure 16. (Continued)

```
     DO YOU WANT TO ADC OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NC

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST CF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORCER  :-
    VARIABLE CODE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          1   70.0000000              2

     THE DATA YCL ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =      1
   VALUE                =      70.0000C
   SUBSCRIPT            =      2
---------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADC OR CHANGE CATA ?
 ***  TYPE IN EITHER  YES  CR  NC

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FCLLOWING CRCER  :-
    VARIABLF CODE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NC DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

         99   .E99999976              1

     THE CATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =      99
   VALUE                =      0.90CCC
   SUBSCRIPT            =      1
---------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADC OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  CR  NO

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST CF THE DATA OR THE NEW VALUES
    IN THE FCLLOWING CRCER  :-
    VARIABLE CCDE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NC DATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

         76   .750000CC0              2
```

Figure 16. (Continued)

```
     THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =     76
   VALUE                =      0.75000
   SUBSCRIPT            =      2
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

N


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


         76   .7499998810E-01          2

     THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =     76
   VALUE                =      0.07500
   SUBSCRIPT            =      2
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
***  TYPE IN EITHER  YES  OR  NO

N


                    *****  R E S U L T S  *****

PROCESS # = 1     PROCESS CODE # =100     INITIAL STATE = 1     FINAL STATE = 2
-------------------------------------------------------------------------------
 1)       1.3380       1.3380       1.1360       0.8490       0.2870       8.31
 2) ************      15.1237 ************      28.9750       1.0000       9.80
 3)     180.0000     980.0000 ************       1.5624 ************     281.23
 4) ************    1113.2795 ************ ************ ************ **********
 5) ************     832.0474      23.6293 ************      70.0000       0.33
 6) ************ ************       0.0539 ************ ************       0.64
 7)      70.0000     793.0024 ************       3.2510 ************     227.56
 8) ************     900.8503 ************ ************ ************ **********
 9) ************     673.2812      49.1669 ************     655.5553       0.07
10) ************ ************       0.1122 ************ ************       0.30
11)          0.0          0.0          0.0          0.0          0.0        0.0
12) ************      53.6630     811.5823 ************          0.0        0.0
13) ************     -53.6630    -811.5823 ************ ************    -212.42
14)          0.0          0.0          0.0          0.0 ************    -158.76
```

Figure 16. (Continued)

```
15) ************* ************* ************* ************* *************       0.0

16) ************* ************* ************* ************* *************       0.03

17)    -110.0000     -186.9575 *************        1.6886 *************     -53.66

18)       0.3889        0.8092        2.0808        0.2227        9.3651 **********

19)       0.0           0.0           0.0           0.0     *************    691.02

20)     771.9854     -208.0146       21.0171 *************     -236.3046       0.90


      DID YOU FORGET TO ENTER OTHER DATA ?
 ***    TYPE IN EITHER  YES  OR  NO

N


      WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
 ***  TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
 ***  TYPE IN EITHER    YES    OR    NO

N


     WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PROCESS  ?
 ***  TYPE IN EITHER     YES    OR    NO

N

################################################################################
  WOULD YOU LIKE TO SOLVE A NEW PROBLEM ?
 *** TYPE IN EITHER     YES    OR    NO
################################################################################

Y
```

Figure 16. (Continued)

The fourth example taken from Van Wylen and Sonntag [9] demonstrates the use of the program for a steady-state, steady-flow of air through a compressor. The Gas Tables are used for obtaining data in this example.

EXAMPLE 4

Air initially at 15 psia and 60°F is compressed to 75 psia and 400°F. The power input to the air under steady-state conditions is 5 hp, and heat loss of 4 Btu/lb occurs during the process. If the changes in potential and kinetic energies are neglected, determine the following using data from the gas tables:

(a) mass flow rate

(b) adiabatic efficiency of the compressor

(c) temperature rise due to irreversibility within the compressor.

In order to solve this example, the values of enthalpy and internal energy at the initial and final temperatures have been found on the Gas Tables. These values together with those given by the problem have been converted to the correct units, then tabulated in Figure 17. The computer output for this example is shown in Figure 18.

	Unit	Process	Initial State	Final State	Flow Type	Device
DESCRIPTION	English	General	I	F	Open	Compressor
CODE NUMBER	2	100	1	2	1	4

	Yes	No
IS IT ADIABATIC?		✓
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	R	M
VALUE					

Data	Variable Code No	Value	Subscript
$P_1 = 2160$	1	2160	1
$T_1 = 520$	2	520	1
$P_2 = 10800$	1	10800	2
$T_2 = 860$	2	860	2
$\dot{W} = -2750$	84	-2750	2
$Q = -3112$	21	-3112	2
$h_1 = 96702$	9	96702	1
$h_2 = 160659$	9	160659	2
$u_1 = 68960$	13	68960	1
$u_2 = 114779$	13	114779	2

Figure 17. The Input Data Tables for Example 4

```
****************************************************************************
    THIS IS A GENERAL PROGRAM TO AID THE SOLUTION OF THERMODYNAMIC PROCESSES
    AND CYCLES BASEC CN IDEAL GAS RELATICNSHIPS
****************************************************************************


     PLEASE ENTER : -
     ----------------
    UNITS OPTICN:-  1  FCR METRIC UNITS , 2  FOR ENGLISH UNITS
    PROCESS CODE NUMBER :-
            ISOBARIC    PRCCESS   10
            ISCTHERMAL PRCCESS   20
            ISENTROPIC PRCCESS   30
            ISCHETRIC  PRCCESS   40
            PCLYTRCPIC PRCCESS   50
            GENERAL    PRCCESS  100
            E  X  I  T            0
   INITIAL STATE CF THE PRCCESS ,
   FINAL STATE OF THE PROCESS : AND
   FLCW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NCN-FLCW

         2        1C0          1          2          1

     PLFASE ENTER THE CEVICE CODE NUMBER :
  ---------------------------------------------
  HEAT EXCHANGER: 1  , TURBINE: 2  , NCZZLE: 3  ,  COMPRESSOR: 4  , CIFFLSER: 5
   PISTON: 6  , CTHERS: 7

         4


     YOU ENTERED THE FCLLOWING DATA :-
 -------------------------------------------------
    UNITS  OPTION         =   2
    PROCESS CODE NUMBER = 10C
    INITIAL STATE        =   1
    FINAL STATE          =   2
    FLOW CONCITION       =   1
    DEVICE CCDE NUMBER  =   4
 -------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

  SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =     7

 ---------------------------------------------------------------------------
      IS IT AN ACIABATIC PROCESS ?
 **  PLEASE ENTER EITHER   YES  CR  NC
 ---------------------------------------------------------------------------
N

 ---------------------------------------------------------------------------
    IS THERE A KINETIC ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  CR  NC
 ---------------------------------------------------------------------------
N

 ---------------------------------------------------------------------------
    IS THERE A POTENTIAL ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  CR  NC
 ---------------------------------------------------------------------------
N

****************************************************************************
 THE VALUES OF THE FOLLOWING CONSTANTS ARE STOREC FOR YCL :-
  RU = 8.315C     SI UNIT        RU = 1545   ENGLISH UNIT
  G  = 9.80       SI UNIT        G  = 32.2   ENGLISH UNIT
  GC = 1.0        SI UNIT        GC = 32.2   ENGLISH UNIT
 IF YOU LIKE TC CHANGE THE VALUF OF EACH CONSTANT REPLACE IT BY A PROPER VALUE
****************************************************************************

    PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNCWN ENTER  C

  .0
```

Figure 18. Computer Print-out of Example 4

```
  PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0
.0
  PLEASE ENTER THE VALUE OF (25):CV , IF IT IS  UNKNOWN ENTER  C
.0
  PLEASE ENTER THE VALUE OF (28):MW , IF IT IS  UNKNOWN ENTER  0
.0
  PLEASE ENTER THE VALUE OF (22):R  , IF IT IS  UNKNOWN ENTER  0
.0

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NC DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          1   2160.00CC0            1

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =     1
   VALUE                =  2160.C000C
   SUBSCRIPT            =     1
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING CRCER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          2   520.C00C00            1

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =     2
   VALUE                =   520.00000
   SUBSCRIPT            =     1
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  CR  NC

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING CRDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO CATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
```

Figure 18. (Continued)

```
          1   1C8CC.CCCO               2

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =       1
   VALUE                = 10800.COOC
   SUBSCRIPT            =       2
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ACC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FCLLCWING CRCER  :-
    VARIABLE CCDE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO CATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          2   86C.COOCCO               2

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =       2
   VALUE                =    86D.00000
   SUBSCRIPT            =       2
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ACC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  CR  NC

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE CATA OR THE NEW VALUES
    IN THE FCLLOWING CRDER  :-
    VARIABLF CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NC DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

         84  -275C.CCCCO               2

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =      84
   VALUE                = -2750.CCOCO
   SUBSCRIPT            =       2
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ACC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y
```

Figure 18. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


         21  -3112.00000              2


     THE DATA YOU ENTERED ARE :-
------------------------------------------------
   VARIABLE CODE NUMBER =     21
   VALUE                = -3112.00000
   SUBSCRIPT            =      2
------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


         9   96702.0000               1


     THE DATA YOU ENTERED ARE :-
------------------------------------------------
   VARIABLE CODE NUMBER =      9
   VALUE                = 96702.0000
   SUBSCRIPT            =      1
------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


         9   160659.000               2


     THE DATA YOU ENTERED ARE :-
------------------------------------------------
   VARIABLE CODE NUMBER =      9
   VALUE                =160659.000
   SUBSCRIPT            =      2
------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y
```

Figure 18. (Continued)

```
    DO YOU WANT TO ACC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  CR  NC

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
   NOW , PLEASE ENTER THE REST CF THE DATA OR THE NEW VALUES
   IN THE FOLLOWING CRCER  :-
   VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
   IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

        13   68960.0CCO              1

    THE DATA YOU ENTERED ARE :-
-----------------------------------------------
  VARIABLE CODE NUMBER =     13
  VALUE                = 68960.0000
  SUBSCRIPT            =      1
-----------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

    DO YOU WANT TO ACC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  CR  NO

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
   NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
   IN THE FCLLCWING CRDER  :-
   VARIABLE CODE NUMPER  ,  VALUE  ,  AND SUBSCRIPT
   IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

        13   114779.C00              2

    THE DATA YOU ENTERED ARE :-
-----------------------------------------------
  VARIABLE CODE NUMBER =     13
  VALUE                =114779.C00
  SUBSCRIPT            =      2
-----------------------------------------------
***IF OK , TYPE IN YES, IF NCT TYPE IN NO

Y

    DO YOU WANT TO ACC OR CHANGE DATA ?
***  TYPE IN EITHER  YES  CR  NO

N

    WOULD YOU LIKE TO SEE THE SCLUTICN PROCEDURE ?
***  TYPE IN EITHER  YES  CR  NC

N
```

Figure 18. (Continued)

```
                    *****  R E S U L T S  *****

 PROCESS # = 1     PROCESS CODE # =100     INITIAL STATE = 1     FINAL STATE = 2
-------------------------------------------------------------------------------------
  1)       1.3959       1.3959     185.9654     132.6154      53.3500     1545.00
  2) ************       0.0410 ************      28.5557      32.2000       32.20
  3)    2160.0000     520.0000 ************      12.8435 ************    27742.00
  4) ************   96702.0000 ************ ************ ************ **********
  5) ************   68560.0000       0.5266 ************ ************ **********
  6) ************ ************       0.4435 ************ ************        0.07
  7)   10800.0000     860.0000 ************       4.2481 ************    45880.00
  8) ************  160659.000  ************ ************ ************ **********
  9) ************  114779.000        0.1742 ************ ************ **********
 10) ************ ************       0.1467 ************ ************        0.23
 11) ************  -67069.0000   -2750.0000 ************    2622.3599 **********
 12) ************  -18138.0000    -743.7041 ************ ************    63957.00
 13) ************  -48931.0000   -2006.2957 ************ ************    63957.00
 14) ************   -3112.0000    -127.6001 ************ ************    45819.00
 15) ************ ************ ************ ************          0.0         0.0
 16) ************ ************ ************ ************ ************        7.69
 17)    8640.0000     340.0000 ************      -8.9954 ************    18138.00
 18)       5.0000       1.6538       0.3308 ************ ************ **********
 19) ************  -56744.5469   -2326.6711 ************          0.0 **********
 20)     825.1350     305.1350      34.8650 ************   56744.5469        0.84

       DID YOU FORGET TO ENTER OTHER DATA ?
 ***     TYPE IN EITHER  YES  OR  NO

N


      WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
 ***  TYPE IN EITHER  YES  OR  NO

N


     WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
     NEW VALUES FOR SOME OF THE VARIABLES  ?
 ***  TYPE IN EITHER    YES    OR    NO

N


      WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
      TO SOLVE THE NEXT PROCESS  ?
 ***  TYPE IN EITHER     YES    OR    NO

N

*******************************************************************************
  WOULD YOU LIKE TO SOLVE A NEW PROBLEM ?
 *** TYPE IN EITHER     YES   OR   NO
*******************************************************************************
YES
```

Figure 18. (Continued)

The required results can be obtained from the output matrix as following:

(a) Mass flow rate = 0.0410 lb_m/min

(b) Adiabatic efficiency = 0.846

(c) Temperature rise = 34.865 °R

The last two examples demonstrates the use of the program for analyzing thermodynamic cycles involving different types of processes and devices. The first example, from Huang [11] presents an air-standard gas turbine cycle, assuming constant specific heats.

EXAMPLE 5

Air air-standard gas turbine cycle operates with air entering the compressor at 0.95 bar and 22°C. The pressure ratio is 6:1, and the air leaves the combustion chamber at 1100°K, the compressor and turbine are only 82 and 85 percent efficient respectively. Compute the actual compressor and turbine work quantities and the thermal efficiency for this cycle.

The processes as described for this cycle are presented on the T-s and P-v diagrams as shown in Figure 19. In order to analyze this cycle by using the program, the quantities are first converted to the appropriate units. Since the approach used in the analysis of a cycle is based on treating each process separately, the data entry of each process for this cycle is tabulated separately as shown in Figure 20. Then these tables are used for solving the problem. The computer print-out for this example is given in Figure 21. The required results can be obtained from the output matrices and the cycle result.

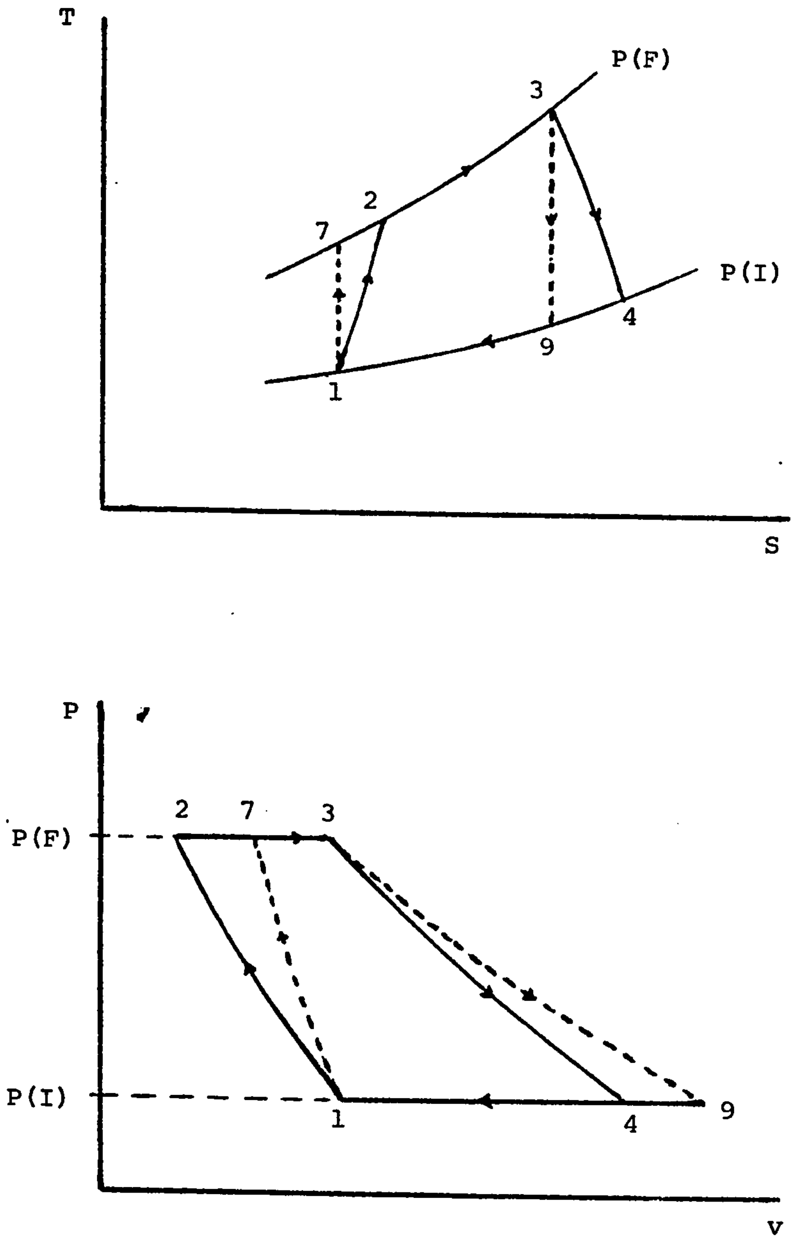


Figure 19. The Ts and Pv Diagrams for Example 5

	Unit	*Process*	*Initial State*	*Final State*	*Flow Type*	*Device*
DESCRIPTION	SI	General	I	F	Open	Compressor
CODE NUMBER	1	100	1	2	1	4

	Yes	*No*
IS IT ADIABATIC?	✓	
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	*R*	*M*
VALUE	1.40	1.005			

Data	*Variable Code No*	*Value*	*Subscript*
$P_1 = 95$	1	95	1
$T_1 = 295$	2	295	1
$P_r = 6$	37	6	2
$\eta = 0.82$	99	0.82	1

Figure 20. The Input Data Tables for Example 5

	Unit	*Process*	*Initial State*	*Final State*	*Flow Type*	*Device*
DESCRIPTION	SI	Isobaric	I	F	Open	Heat Exchanger
CODE NUMBER	1	10	2	3	1	1

	Yes	*No*
IS IT ADIABATIC?		✓
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	*R*	*M*
VALUE	1.40	1.005			

Data	*Variable Code No*	*Value*	*Subscript*
$T_3 = 1100$	2	1100	3
$W = 0$	34	0	3

Figure 20. (Continued)

	Unit	Process	Initial State	Final State	Flow Type	Device
DESCRIPTION	SI	General	I	F	Open	Turbine
CODE NUMBER	1	100	3	4	1	2

	Yes	No
IS IT ADIABATIC?	✓	
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	R	M
VALUE	1.40	1.005			

Data	Variable Code No	Value	Subscript
$P_r = 0.1667$	37	0.1667	4
$\eta = 0.85$	99	0.85	3

Figure 20. (Continued)

	Unit	*Process*	*Initial State*	*Final State*	*Flow Type*	*Device*
DESCRIPTION	SI	Isobaric	I	F	Open	Heat Exchanger
CODE NUMBER	1	10	4	1	1	1

	Yes	*No*
IS IT ADIABATIC?		✓
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	*R*	*M*
VALUE	1.40	1.005			

Data	*Variable Code No*	*Value*	*Subscript*
W = 0	34	0	1

Figure 20. (Continued)

```
****************************************************************************************
    THIS IS A GENERAL FROGRAM TO AIC THE SOLUTION OF THFRMODYNAMIC PROCESSES
    AND CYCLES BASEC ON ICEAL GAS RELATIONSHIPS
****************************************************************************************


  PLEASE ENTER : -
  -----------------
 UNITS OPTION:-  1  FCR METRIC UNITS , 2  FOR ENGLISH UNITS
 PROCESS COCE NUMBER :-
         ISOBARIC   PRCCESS   10
         ISCTHERMAL PRCCESS   20
         ISENTROPIC PROCESS   30
         ISCHETRIC  PRCCESS   40
         PCLYTRCPIC PRCCESS   50
         GENERAL    PRCCESS  100
         E  X  I  T            0
 INITIAL STATE CF THE PROCESS ,
 FINAL STATE OF THE PRCCESS : AND
 FLCW CONDITICN:-  1  FOR STEADY FLCW , 0  FOR NCN-FLCW

          1          100           1           2           1

    PLEASE ENTER THE CEVICE CODE NUMBER :
---------------------------------------------
 HEAT FXCHANGER: 1  , TURBINE: 2  , NCZZLE: 3  ,  CCMPRESSOR: 4  , CIFFUSER: 5
  PISTCN: 6  , CTHERS: 7

          4


     YOU ENTERED THE FCLLOWING DATA :-
-----------------------------------------------------
   UNITS  OPTION        =   1
   PROCESS CCDE NUMBER = 100
   INITIAL STATE        =   1
   FINAL STATE          =   2
   FLOW CCNDITION       =   1
   DEVICE CCDE NUMBER   =   4
-----------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NO  .

Y

  SUBSCRIPT OF ISENTRCPIC  FINAL  STATE   =     7

----------------------------------------------------------------------------------
      IS IT AN ACIABATIC PROCESS ?
 **  PLEASE ENTER EITHER   YES  OR  NO
----------------------------------------------------------------------------------
Y

----------------------------------------------------------------------------------
   IS THERE A KINETIC ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  OR  NC
----------------------------------------------------------------------------------
N

----------------------------------------------------------------------------------
   IS THERE A POTENTIAL ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  OR  NC
----------------------------------------------------------------------------------
N

##################################################################################
 THE VALUES OF THE FOLLOWING CONSTANTS ARE STORED FOR YCU :-
  RU = 8.3150      SI UNIT       RU = 1545    ENGLISH UNIT
  G  = 9.80        SI UNIT       G  = 32.2    ENGLISH UNIT
  GC = 1.0         SI UNIT       GC = 32.2    ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PRCPER VALUE
##################################################################################

     PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNCWN ENTER  C

   1.39999962
```

Figure 21. Computer Print-out of Example 5

```
PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0

1.00500311

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
   NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
   IN THE FOLLOWING ORDER  :-
   VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
   IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

         1   95.0000000              1

    THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =      1
   VALUE                =     95.00000
   SUBSCRIPT            =      1
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
   NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
   IN THE FOLLOWING ORDER  :-
   VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
   IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

         2   295.000000              1

    THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =      2
   VALUE                =    295.00000
   SUBSCRIPT            =      1
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
   NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
   IN THE FOLLOWING ORDER  :-
   VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
   IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

        37   6.00000000              2

    THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =     37
   VALUE                =      6.00000
   SUBSCRIPT            =      2
--------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y
```

Figure 21. (Continued)

```
    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


         99   .819999993              1

     THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =     99
   VALUE                =      0.82000
   SUBSCRIPT            =      1
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
***  TYPE IN EITHER  YES  OR  NO

N
```

***** R E S U L T S *****

PROCESS # = 1   PROCESS CODE # =100   INITIAL STATE = 1   FINAL STATE = 2

1)	1.4000	1.4000	1.0050	0.7179	0.2871	8.31
2)	************	************	************	28.9577	1.0000	9.80
3)	95.0000	255.0000	************	0.6517	************	84.70
4)	************	256.4749	************	************	************	**********
5)	************	211.7679	************	************	************	**********
6)	************	************	0.0308	************	************	1.12
7)	570.0000	535.5007	************	0.2658	************	153.76
8)	************	538.1782	************	************	************	**********
9)	************	384.4131	************	************	************	**********
10)	************	************	0.0093	************	************	**********
11)	************	-241.7034	************	************	************	**********
12)	************	-69.0581	************	************	************	241.70
13)	************	-172.6453	************	************	************	241.70
14)	0.0	0.0	0.0	0.0	************	172.64
15)	************	************	************	************	0.0	0.0
16)	************	************	************	************	************	0.08
17)	475.0000	240.5008	************	-0.6219	************	69.05
18)	6.0000	1.8153	0.3025	************	************	**********
19)	************	-158.1568	************	************	0.0	**********
20)	492.2107	157.2107	43.2900	************	158.1568	0.82

Figure 21. (Continued)

```
     DID YOU FCRGET TC ENTER CTHER DATA ?
***   TYPE IN EITHER  YES  OR  NO

N


     WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
***  TYPE IN EITHER  YES  CR  NC

N

     WOULD YCU LIKE TC SCLVE THE SAME PROCESS WITH
     NEW VALUES FCR SCME OF THE VARIABLES  ?
***  TYPE IN EITHER   YES   OR   NO

N


     WOULD YCU LIKE TC KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PROCESS  ?
***  TYPE IN EITHER    YES   OR   NO

YES

    PLEASE ENTER : -
   -----------------
   UNITS OPTION:-  1  FCR METRIC UNITS , 2  FOR ENGLISH UNITS
   PROCESS CCDE NUMBER :-
          ISOBARIC    PRCCESS   10
          ISOTHERMAL  PRCCESS   20
          ISENTRCPIC  PRCCESS   30
          ISCMETRIC   PRCCESS   40
          PCLYTRCPIC  PRCCESS   50
          GENERAL     PRCCESS  100
          E  X  I  T             0
   INITIAL STATE OF THE PRCCESS ,
   FINAL STATE OF THE PRCCESS : AND
   FLOW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NCN-FLCW

          1         10          2          3          1

     PLEASE ENTER THE CEVICE CODE NUMBER :
  -----------------------------------------
  HEAT EXCHANGER: 1   , TURBINE: 2   , NOZZLE: 3   ,  CCMPRESSOR: 4   , CIFFUSER: 5
   PISTON: 6   , CTHERS: 7

          1


     YOU ENTERED THE FOLLOWING DATA :-
  ------------------------------------------------
   UNITS  OPTION       =   1
   PROCESS CODE NUMBER =  10
   INITIAL  STATE      =   2
   FINAL  STATE        =   3
   FLOW CONDITION      =   1
   DEVICE CCDE NUMBER  =   1
  ------------------------------------------------
  *** IF OK , TYPE IN YES, IF NOT TYPE IN NO

 Y

   SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =     8

 ------------------------------------------------------------------------
      IS IT AN ADIABATIC PROCESS ?
  **  PLEASE ENTER EITHER   YES  OR  NO
 ------------------------------------------------------------------------
 N

 ------------------------------------------------------------------------
   IS THERE A KINETIC ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  CR  NC
 ------------------------------------------------------------------------
 N

 ------------------------------------------------------------------------
   IS THERE A PCTENTIAL ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  CR  NC
 ------------------------------------------------------------------------
 N
```

Figure 21. (Continued)

```
################################################################################
 THE VALUES OF THE FCLLCWING CONSTANTS ARE STOREC FOR YCU :-
  RU = 8.3150      SI UNIT       RU = 1545    ENGLISH UNIT
  G  = 9.80        SI UNIT       G  = 32.2    ENGLISH UNIT
  GC = 1.0         SI UNIT       GC = 32.2    ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PRCPER VALUE
################################################################################

     PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNCWN ENTER  0

   1.35595562

     PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNCWN ENTER  0

   1.00500011


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING CRCER  :-
    VARIABLE CCDE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          2   1100.00CC0              3

     THE CATA YOU ENTERED ARE :-
-------------------------------------------------
   VARIABLE CODE NUMBEF =      2
   VALUE                =   1100.000C0
   SUBSCRIPT            =      3
-------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TC ACC OR CHANGE CATA ?
 ***  TYPE IN EITHER  YES  OR  NC

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING CRCER  :-
    VARIABLE CCDE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NO CATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


         34    .0                     3

     THE DATA YOU ENTERED ARE :-
-------------------------------------------------
   VARIABLE CODE NUMBER =      34
   VALUE                =      0.0
   SUBSCRIPT            =      3
-------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TC ADC OR CHANGE CATA ?
 ***  TYPE IN EITHER  YES  CR  NO

N


     WOULD YOU LIKE TO SEE THE SOLUTICN PROCEDURE ?
 ***  TYPE IN EITHER  YES  CR  NO

N
```

Figure 21. (Continued)

```
                    *****  R E S U L T S  *****

 PROCESS # = 2     PROCESS CODE # = 10     INITIAL STATE = 2     FINAL STATE = 3
-------------------------------------------------------------------------------
  1)       0.0         1.4000       1.0050       0.7179       0.2871        8.31
  2) ************ ************ ************     28.9577       1.0000        9.80
  3)     570.0000     535.5007 ************       0.2658 ************     153.76
  4) ************     538.1782 ************ ************ ************ **********
  5) ************     384.4131 ************ ************ ************ **********
  6) ************ ************       0.0093 ************ ************       3.70
  7)     570.0000    1100.0000 ************       0.5541 ************     315.85
  8) ************    1105.5000 ************ ************ ************ **********
  9) ************     789.6431 ************ ************ ************ **********
 10) ************ ************       0.0191 ************ ************       1.80
 11) ************      0.0     ************ ************ ************ **********
 12) ************    -162.0916 ************ ************ ************     567.32
 13) ************     162.0916 ************ ************ ************     567.32
 14) ************     567.3218 ************ ************ ************     405.22
 15) ************ ************ ************ ************      0.0          0.0
 16) ************ ************ ************ ************ ************       0.72
 17)       0.0        564.4593 ************       0.2844 ************     162.09
 18)       1.0000       2.0542       2.0542 ************ ************ **********
 19) ************ ************ ************ ************      0.0     **********
 20) ************ ************ ************ ************ ************ **********


     DID YOU FORGET TO ENTER OTHER DATA ?
***    TYPE IN EITHER  YES  OR  NO
N


     WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
***  TYPE IN EITHER  YES  OR  NO
N


    WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
***  TYPE IN EITHER   YES   OR   NO
N


     WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PROCESS  ?
***  TYPE IN EITHER    YES   OR   NO
Y
```

Figure 21. (Continued)

```
 PLEASE ENTER : -
-----------------
UNITS OPTION:-  1  FOR METRIC UNITS , 2  FOR ENGLISH UNITS
PROCESS CODE NUMBER :-
        ISOBARIC    PROCESS   10
        ISOTHERMAL PROCESS   20
        ISENTROPIC PROCESS   30
        ISOMETRIC  PROCESS   40
        POLYTROPIC PROCESS   50
        GENERAL    PROCESS  100
        E  X  I  T            0
 INITIAL STATE OF THE PROCESS ,
 FINAL STATE OF THE PROCESS ; AND
 FLOW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NON-FLOW

         1          100           3           4           1

   PLEASE ENTER THE DEVICE CODE NUMBER :
----------------------------------------------
HEAT EXCHANGER: 1  , TURBINE: 2  , NOZZLE: 3  ,  COMPRESSOR: 4  , DIFFUSER: 5
 PISTON: 6  , OTHERS: 7

         2


    YOU ENTERED THE FOLLOWING DATA :-
--------------------------------------------------
   UNITS  OPTION        =   1
   PROCESS CODE NUMBER = 100
   INITIAL STATE        =   3
   FINAL STATE          =   4
   FLOW CONDITION       =   1
   DEVICE CODE NUMBER   =   2
--------------------------------------------------
*** IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

  SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =      9

--------------------------------------------------------------------------------
     IS IT AN ADIABATIC PROCESS ?
**  PLEASE ENTER EITHER   YES  OR  NO
--------------------------------------------------------------------------------
Y

--------------------------------------------------------------------------------
   IS THERE A KINETIC ENERGY CHANGE ?
**  PLEASE ENTER EITHER   YES  OR  NO
--------------------------------------------------------------------------------
N

--------------------------------------------------------------------------------
   IS THERE A POTENTIAL ENERGY CHANGE ?
**  PLEASE ENTER EITHER   YES  OR  NO
--------------------------------------------------------------------------------
N

################################################################################
 THE VALUES OF THE FOLLOWING CONSTANTS ARE STORED FOR YOU :-
  RU = 8.3150      SI UNIT       RU = 1545    ENGLISH UNIT
  G  = 9.80        SI UNIT       G  = 32.2    ENGLISH UNIT
  GC = 1.0         SI UNIT       GC = 32.2    ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PROPER VALUE
################################################################################

   PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNOWN ENTER  0

 1.39999962

   PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0

 1.00500011
```

Figure 21. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          37   .166666667              4

      THE DATA YOU ENTERED ARE :-
-----------------------------------------------
   VARIABLE CODE NUMBER =     37
   VALUE                =      0.16667
   SUBSCRIPT            =      4
-----------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

 Y

     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

 Y

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          99   .850000024              3

      THE DATA YOU ENTERED ARE :-
-----------------------------------------------
   VARIABLE CODE NUMBER =     99
   VALUE                =      0.85000
   SUBSCRIPT            =      3
-----------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

 Y

     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

 N

     WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
 ***  TYPE IN EITHER  YES  OR  NO

 N


                    *****  R E S U L T S  *****

 PROCESS # = 3     PROCESS CODE # =100     INITIAL STATE = 3     FINAL STATE = 4
-----------------------------------------------------------------------------------
  1)        1.4000        1.4000        1.0050        0.7179        0.2671        8.31

  2) ************ ************ ************       28.9577        1.0000        9.80

  3)      570.0000     1100.0000 ************        0.5541 ************      315.85

  4) ************     1105.5000 ************ ************ ************ **********

  5) ************      789.6431 ************ ************ ************ **********

  6) ************ ************        0.0191 ************ ************        1.80
```

Figure 21. (Continued)

```
 7)      95.0000     725.3799 ************       2.1525 ************     208.28
 8) ************     729.0066 ************ ************ ************ **********
 9) ************     520.7192 ************ ************ ************ **********
10) ************ ************       0.0757 ************ ************ **********
11) ************     376.4934 ************ ************ ************ **********
12) ************     107.5656 ************ ************ ************    -376.49
13) ************     268.9238 ************ ************ ************    -376.49
14)        0.0          0.0          0.0          0.0  ************    -268.92
15) ************ ************ ************ ************          0.0       0.0
16) ************ ************ ************ ************ ************      0.09
17)    -475.0000    -374.6201 ************       1.6364 ************   -107.56
18)       0.1667       0.6594       3.9566 ************ ************ **********
19) ************     442.9336 ************ ************          0.0 **********
20)     659.2700    -440.7300      66.1095 ************    -442.9336       0.85

    DID YOU FORGET TO ENTER OTHER DATA ?
***   TYPE IN EITHER  YES  OR  NO

N

    WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
***  TYPE IN EITHER  YES  OR  NO

N

   WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
   NEW VALUES FOR SOME OF THE VARIABLES  ?
***  TYPE IN EITHER    YES    OR    NO

N

    WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
    TO SOLVE THE NEXT PROCESS  ?
***  TYPE IN EITHER    YES    OR    NO

Y

  PLEASE ENTER : -
  ----------------
 UNITS OPTION:-  1  FOR METRIC UNITS , 2  FOR ENGLISH UNITS
 PROCESS CODE NUMBER :-
         ISOBARIC    PROCESS   10
         ISOTHERMAL  PROCESS   20
         ISENTROPIC  PROCESS   30
         ISOMETRIC   PROCESS   40
         POLYTROPIC  PROCESS   50
         GENERAL     PROCESS  100
         E  X  I  T             0
 INITIAL STATE OF THE PROCESS ,
 FINAL STATE OF THE PROCESS ; AND
 FLOW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NON-FLOW

         1          10          4           1           1

   PLEASE ENTER THE DEVICE CODE NUMBER :
--  -----------------------------------
HEAT EXCHANGER: 1  , TURBINE: 2  , NOZZLE: 3  ,  COMPRESSOR: 4  , DIFFUSER: 5
 PISTON: 6  , OTHERS: 7

         1
```

Figure 21. (Continued)

```
     YOU ENTERED THE FCLLCWING DATA :-
 ------------------------------------------------
    UNITS  OPTION        =   1
    PROCESS CODE NUMBER =  10
    INITIAL STATE        =   4
    FINAL STATE          =   1
    FLOW CONDITION       =   1
    DEVICE CCDE NUMBER   =   1
 ------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NO

 Y

   SUBSCRIPT OF ISENTRCFIC  FINAL  STATE   =     6

 --------------------------------------------------------------------------
      IS IT AN ACIABATIC PRCCESS ?
 **  PLEASE ENTER EITHER   YES  CR  NC
 --------------------------------------------------------------------------
 N

 --------------------------------------------------------------------------
    IS THERE A KINETIC ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  OR  NO
 --------------------------------------------------------------------------
 N

 --------------------------------------------------------------------------
    IS THERE A POTENTIAL ENERGY CHANGE ?
 **  PLEASE ENTER EITHER   YES  CR  NO
 --------------------------------------------------------------------------
 N

 **************************************************************************
  THE VALUES OF THE FOLLOWING CONSTANTS ARE STOREC FOR YCU :-
   RU = 8.3150      SI UNIT        RU = 1545   ENGLISH UNIT
   G  = 9.80        SI UNIT        G  = 32.2   ENGLISH UNIT
   GC = 1.0         SI UNIT        GC = 32.2   ENGLISH UNIT
  IF YOU LIKE TO CHANGE THE VALUF OF EACH CONSTANT REPLACE IT BY A PRCPER VALUE
 **************************************************************************

     PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNCWN ENTER  C

   1.39999962

     PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  C

   1.00500011

 *-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING CRDER  :-
    VARIABLE CODE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETFR : 0  C  0
 -*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

        34    .C                          1

     THE DATA YOU ENTERED ARE :-
 ------------------------------------------------
   VARIABLE CODE NUMBER =    34
   VALUE                =     0.0
   SUBSCRIPT            =     1
 ------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

 Y
```

Figure 21. (Continued)

```
    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

N

    WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
***  TYPE IN EITHER  YES  OR  NO

N
```

***** R E S U L T S *****

PROCESS # = 4 | PROCESS CODE # = 10 | INITIAL STATE = 4 | FINAL STATE = 1

1)	0.0	1.4000	1.0050	0.7179	0.2871	8.31
2)	************	************	************	28.9577	1.0000	9.80
3)	95.0000	725.3799	************	2.1925	************	208.28
4)	************	729.0066	************	************	************	**********
5)	************	520.7192	************	************	************	**********
6)	************	************	0.0757	************	************	0.45
7)	95.0000	295.0000	************	0.8917	************	84.70
8)	************	256.4749	************	************	************	**********
9)	************	211.7679	************	************	************	**********
10)	************	************	0.0308	************	************	1.12
11)	************	0.0	************	************	************	**********
12)	************	123.5802	************	************	************	-432.53
13)	************	-123.5802	************	************	************	-432.53
14)	************	-432.5317	************	************	************	-308.95
15)	************	************	************	************	0.0	0.0
16)	************	************	************	************	************	-0.90
17)	0.0	-430.3799	************	-1.3008	************	-123.58
18)	1.0000	0.4067	0.4067	************	************	**********
19)	************	************	************	************	0.0	**********
20)	************	************	************	************	************	**********

```
    DID YOU FORGET TO ENTER OTHER DATA ?
***   TYPE IN EITHER  YES  OR  NO

N

    WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
***  TYPE IN EITHER  YES  OR  NO

N
```

Figure 21. (Continued)

```
    WOULD YOU LIKE TO SCLVE THE SAME PROCESS WITH
    NEW VALUES FCR SOME OF THE VARIABLES  ?
 ***  TYPE IN EITHER    YES   CR   NC

N

     WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PRCCESS  ?
 ***  TYPE IN EITHER     YES   OR   NO

N
----------------------------------------------------------------------------------
                         C Y C L E   R E S U L T S

 INPUT HEAT/MASS =  567.3218          CUTPUT HEAT/MASS    = -432.5317
 INPUT WORK/MASS = -241.7034          OUTPUT WORK/MASS    =  376.4534
 NET WORK / MASS =  134.7900          THERMAL EFFICIENCY =    0.2376
----------------------------------------------------------------------------------

    WOULD YOU LIKE TO SOLVE THE SAME CYCLE WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
 ***  TYPE IN EITHER  YES  CR  NC

NO
**********************************************************************************
  WOULD YOU LIKE TO SOLVE A NEW PROBLEM ?
 *** TYPE IN EITHER    YES   OR   NC
**********************************************************************************

YES
```

Figure 21. (Continued)

The compressor work input exists in the matrix of process (1-2), while the turbine output is in the matrix of process (3-4). Therefore, the required results are:

Actual compressor work	=	241.7034 KJ/Kg
Actual turbine work	=	376.50 KJ/Kg
Cycle thermal efficiency	=	23.76 %

The last example demonstrates the use of the program in determining the effects of varying the values of compression ratio on the performance of an air-standard dual cycle. This example is taken from Van Wylen and Sonntag [9].

EXAMPLE 6

The intake conditions for an air-standard dual cycle are 0.95 bar and 17°C. The pressure ratio during constant-volume heating is 1.5:1 and the volume ratio during the constant-pressure part of the heating process is 2:1. Use an air-standard cycle for which K and c_p are 1.40 and 1.0038 KJ/Kg°K, respectively. Calculate the temperatures and pressures around the cycle, the heat input and heat rejection, the net work, and the thermal efficiency if the intake compression ratio is 3, 6, 9, 12, 15, and 18. Plot the compression ratio versus the thermal efficiency of the cycle. The T-s and P-v diagrams are shown in Figure 22.

Since this cycle consists of five processes, five sets of input data tables are needed. The data for each process have been converted to the proper units, then tabulated as shown in Figure 23. The values of specific heats for all processes involved have been assumed constant and having the same values. Also, the values of volume ratios are considered for the first input of the compression ratios. Using the similar procedure like the previous example, the solution for this example is carried out on

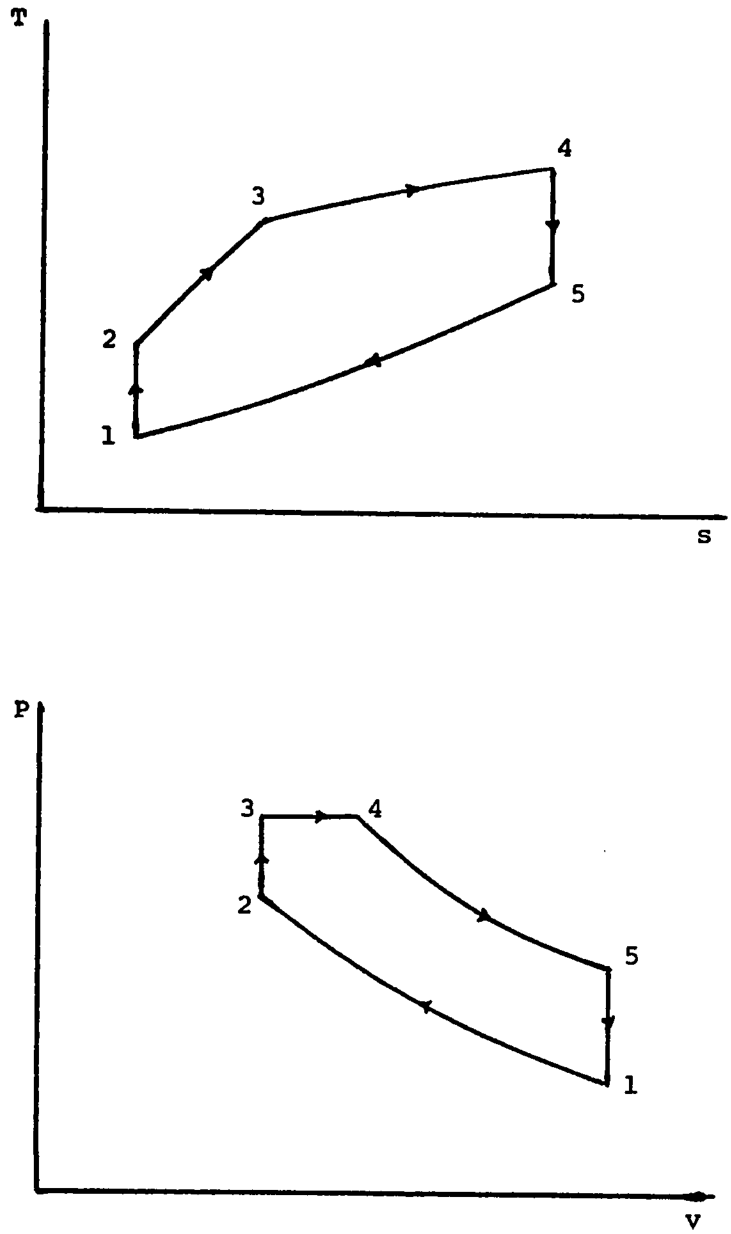


Figure 22. The Ts and Pv Diagrams
for Example 6

	Unit	Process	Initial State	Final State	Flow Type	Device
DESCRIPTION	SI	General	I	F	Open	Piston
CODE NUMBER	1	30	1	2	1	6

	Yes	No
IS IT ADIABATIC?	✓	
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	R	M
VALUE	1.40	1.0038			

Data	Variable Code No	Value	Subscript
$P_1 = 95$	1	95	1
$T_1 = 290$	2	290	1
$V_r = 0.333$*	35	0.333	2

* For Compression Ratio 3

Figure 23. The Input Data Tables for Example 6

	Unit	Process	Initial State	Final State	Flow Type	Device
DESCRIPTION	SI	Isometric	I	F	Open	Piston
CODE NUMBER	1	40	2	3	1	6

	Yes	No
IS IT ADIABATIC?		✓
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	R	M
VALUE	1.40	1.0038			

Data	Variable Code No	Value	Subscript
$P_r = 1.5$	37	1.5	3

Figure 23. (Continued)

	Unit	*Process*	*Initial State*	*Final State*	*Flow Type*	*Device*
DESCRIPTION	SI	Isobaric	I	F	Open	Piston
CODE NUMBER	1	10	3	4	1	6

	Yes	*No*
IS IT ADIABATIC?		✓
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	*R*	*M*
VALUE	1.40	1.0038			

Data	*Variable Code No*	*Value*	*Subscript*
$V_r = 2$	35	2	4

Figure 23. (Continued)

	Unit	*Process*	*Initial State*	*Final State*	*Flow Type*	*Device*
DESCRIPTION	SI	Isentropic	I	F	Open	Piston
CODE NUMBER	1	30	4	5	1	6

	Yes	*No*
IS IT ADIABATIC?	√	
IS THERE EXTERNAL WORK?		√
IS THERE KINETIC ENERGY CHANGE?		√
IS THERE POTENTIAL ENERGY CHANGE?		√

	K	C_p	C_v	*R*	*M*
VALUE	1.40	1.0038			

Data	*Variable Code No*	*Value*	*Subscript*
$V_r = 1.5$*	35	1.5	5

* For Compression Ratio 3

Figure 23. (Continued)

	Unit	*Process*	*Initial State*	*Final State*	*Flow Type*	*Device*
DESCRIPTION	SI	Isometric	I	F	Open	Piston
CODE NUMBER	1	40	5	1	1	6

	Yes	*No*
IS IT ADIABATIC?		✓
IS THERE EXTERNAL WORK?		✓
IS THERE KINETIC ENERGY CHANGE?		✓
IS THERE POTENTIAL ENERGY CHANGE?		✓

	K	C_p	C_v	*R*	*M*
VALUE	1.40	1.0038			

Data	*Variable Code No*	*Value*	*Subscript*
W = 0	34	0	1

Figure 23. (Continued)

the computer as shown in Figure 24. The answers of the first inquiry on temperatures and pressures around the cycle can be obtained from the output matrices for each process. While the answers of other inquiries about the cycle can be determined from the cycle results. The procedure used to solve for the required quantities with different values of compression ratios can be done easily. The user needs only to enter the new value of V_r, after entering the initial and final states of its process. When the new value of V_r has been entered, the computer displayed immediately the new output matrices for all the executed processes as well as the cycle results. There is no need of entering other fixed data.

Now, from the values of compression ratios and their corresponding cycle thermal efficiencies, one can plot the relationship according to Figure 25.

```
*************************************************************************************
    THIS IS A GENERAL PROGRAM TO AID THE SOLUTION OF THERMODYNAMIC PROCESSES
    AND CYCLES BASED ON IDEAL GAS RELATIONSHIPS
*************************************************************************************


   PLEASE ENTER : -
  -----------------

 UNITS OPTION:-  1  FOR METRIC UNITS , 2  FOR ENGLISH UNITS
 PROCESS CODE NUMBER :-
        ISOBARIC    PROCESS   10
        ISOTHERMAL  PROCESS   20
        ISENTROPIC  PROCESS   30
        ISOMETRIC   PROCESS   40
        POLYTROPIC  PROCESS   50
        GENERAL     PROCESS  100
        E  X  I  T             0
 INITIAL STATE OF THE PROCESS ,
 FINAL STATE OF THE PROCESS : AND
 FLOW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NON-FLOW

        1          30           1           2           1

   PLEASE ENTER THE DEVICE CODE NUMBER :
-------------------------------------------
HEAT EXCHANGER: 1   , TURBINE: 2  , NOZZLE: 3   ,  COMPRESSOR: 4   , DIFFUSER: 5
 PISTON: 6   , OTHERS: 7

        6


    YOU ENTERED THE FOLLOWING DATA :-
---------------------------------------------------
  UNITS  OPTION        =   1
  PROCESS CODE NUMBER =  30
  INITIAL STATE        =   1
  FINAL STATE          =   2
  FLOW CONDITION       =   1
  DEVICE CODE NUMBER   =   6
---------------------------------------------------
*** IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

 SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =      7

--------------------------------------------------------------------------------
     IS THERE AN EXTERNAL WORK TERM ?
 **  PLEASE ENTER EITHER   YES  OR  NO
--------------------------------------------------------------------------------
N

################################################################################
THE VALUES OF THE FOLLOWING CONSTANTS ARE STORED FOR YOU :-
 RU = 8.3150      SI UNIT        RU = 1545    ENGLISH UNIT
 G  = 9.80        SI UNIT        G  = 32.2    ENGLISH UNIT
 GC = 1.0         SI UNIT        GC = 32.2    ENGLISH UNIT
IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PROPER VALUE
################################################################################

   PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNOWN ENTER  0

 1.39999962

   PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0

 1.00380039

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
   NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
   IN THE FOLLOWING ORDER  :-
   VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
   IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


       35   .333333015           2
```

Figure 24. Computer Print-out of Example 6

```
     THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      0.33333
   SUBSCRIPT            =      2
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          1   95.0000000              1

     THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =      1
   VALUE                =     95.00000
   SUBSCRIPT            =      1
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

Y


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          2   290.000000              1

     THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =      2
   VALUE                =    290.00000
   SUBSCRIPT            =      1
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
***  TYPE IN EITHER  YES  OR  NO

N
```

Figure 24. (Continued)

```
                    *****  R E S U L T S  *****

 PROCESS # = 1     PROCESS CODE # = 30     INITIAL STATE = 1     FINAL STATE = 2
--------------------------------------------------------------------------------
  1)       1.4000       1.4000       1.0038       0.7170       0.2868       8.31

  2) ************ ************ ************      28.9923 ************ **********

  3)      95.0000     290.0000 ************       0.6755 ************      83.17

  4) ************     251.1021 ************     207.9301 ************ **********

  5) ************     207.9301 ************ ************ ************ **********

  6) ************ ************       0.0302 ************ ************       1.14

  7)     442.2759     450.0352 ************       0.2518 ************     129.07

  8) ************     451.7454 ************     322.6753 ************ **********

  9) ************     322.6753 ************ ************ ************ **********

 10) ************ ************       0.0101 ************ ************       3.42

 11) ************    -114.7452 ************ ************ ************ **********

 12) ************    -114.7452 ************ ************ ************     114.74

 13)          0.0          0.0          0.0          0.0 ************     100.64

 14)          0.0          0.0          0.0          0.0 ************     114.74

 15) ************ ************ ************ ************ ************ **********

 16) ************ ************ ************ ************          0.0        0.0

 17)     347.2759     160.0351 ************      -0.5837 ************      45.69

 18)       4.6555       1.5518       0.3333 ************ ************ **********

 19) ************ ************ ************ ************ ************ **********

 20) ************ ************ ************ ************ ************ **********


     DID YOU FORGET TO ENTER OTHER DATA ?
 ***   TYPE IN EITHER  YES  OR  NO

N

     WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
 ***  TYPE IN EITHER  YES  OR  NO

N

     WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
     NEW VALUES FOR SOME OF THE VARIABLES  ?
 ***  TYPE IN EITHER   YES   OR   NO

N

     WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PROCESS  ?
 ***  TYPE IN EITHER   YES   OR   NO

Y
```

Figure 24. (Continued)

```
 PLEASE ENTER : -
 ------------------
 UNITS OPTION:-  1  FCR METRIC UNITS , 2  FOR ENGLISH UNITS
 PRCCESS CCDE NUMBER :-
          ISOBARIC   PROCESS   10
          ISOTHERMAL PROCESS   20
          ISENTRCPIC PRCCESS   30
          ISCMETRIC  PRCCESS   40
          PCLYTRCPIC PRCCESS   50
          GENERAL    PRCCESS  100
          E  X  I  T            0
 INITIAL STATE CF THE PRCCESS ,
 FINAL STATE OF THE PRCCESS : AND
 FLCW CONDITION:-  1  FOR STEADY FLCW , 0  FOR NCN-FLCW

          1        40          2          3          1

   PLEASE ENTER THE DEVICE CODE NUMBER :
 ---------------------------------------------
 HEAT EXCHANGER: 1  , TURBINE: 2  , NCZZLE: 3  ,  COMPRESSCR: 4  , DIFFUSER: 5
  PISTON: 6  , OTHERS: 7

          6


    YOU ENTEREC THE FCLLCWING DATA :-
 ---------------------------------------------------
   UNITS  OPTION        =   1
   PROCESS CODE NUMBER =  40
   INITIAL STATE       =   2
   FINAL  STATE        =   3
   FLOW CCNDITION      =   1
   DEVICE CCDE NUMBER  =   6
 ---------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NC

Y

  SUBSCRIPT OF ISENTRCPIC  FINAL  STATE   =     8

 --------------------------------------------------------------------------------
      IS IT AN ADIABATIC PRCCESS ?
 **  PLEASE ENTER EITHER   YES  OR  NC
 --------------------------------------------------------------------------------
N

 --------------------------------------------------------------------------------
      IS THERE AN EXTERNAL WORK TERM ?
 **  PLEASE ENTER EITHER   YES  OR  NC
 --------------------------------------------------------------------------------
N

################################################################################
 THE VALUES OF THE FOLLOWING CONSTANTS ARE STORED FOR YCU :-
  RU = 8.3150     SI UNIT       RU = 1545   ENGLISH UNIT
  G  = 9.80       SI UNIT       G  = 32.2   ENGLISH UNIT
  GC = 1.0        SI UNIT       GC = 32.2   ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PRCPER VALUE
################################################################################

    PLEASE ENTER THE VALUE CF (26):K , IF IT IS  UNKNCWN ENTER  C

  1.39999962

    PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNCWN ENTER  C

  1.00380039


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FCLLCWING CRCER  :-
    VARIABLE CCDE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO CATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


      37   1.50000000            3
```

Figure 24. (Continued)

```
     THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =      37
   VALUE                =      1.5000C
   SUBSCRIPT            =      3
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


     DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

N


     WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
***  TYPE IN EITHER  YES  OR  NO

N


                         ***** R E S U L T S *****

PROCESS # = 2     PROCESS CODE # = 40     INITIAL STATE = 2     FINAL STATE = 3
----------------------------------------------------------------------------------
 1) ************     1.4000       1.0038       0.7170       0.2868         8.31

 2) ************ ************ ************    28.5523 ************ **********

 3)    442.2755     450.0352 ************       0.2918 ************     129.07

 4) ************     451.7454 ************     322.6753 ************ **********

 5) ************     322.6753 ************ ************ ************ **********

 6) ************ ************       C.0101 ************ ************       3.42

 7)    663.4138     675.0527 ************       0.2918 ************     193.60

 8) ************     677.6182 ************     484.0129 ************ **********

 9) ************     484.0129 ************ ************ ************ **********

10) ************ ************       C.0101 ************ ************       3.42

11)        C.0          0.0          C.0          0.C       ************ **********

12)        C.0          0.0          C.0          0.C       ************     161.33

13)        C.0          0.0          C.0          0.6       ************     225.87

14) ************     161.3376 ************ ************ ************     161.33

15) ************ ************ ************ ************ ************ **********

16) ************ ************ ************ ************ ************       0.29

17)    221.1379     225.0175       C.0          0.0       ************      64.53

18)      1.5000       1.5000       1.0000 ************ ************ **********

19) ************ ************ ************ ************ ************ **********

20) ************ ************ ************ ************ ************ **********


    DID YOU FORGET TO ENTER OTHER DATA ?
***   TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
***  TYPE IN EITHER  YES  OR  NO

N
```

Figure 24. (Continued)

```
    WOULD YCU LIKE TO SOLVE THE SAME PROCESS WITH
    NEW VALLES FCR SCME OF THE VARIABLES  ?
 ***  TYPE IN EITHER   YES   OR   NC

N

     WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PROCESS  ?
 ***  TYPE IN EITHER    YES   CR   NO

Y

   PLFASE ENTER : -
  ------------------
  UNITS OPTION:-  1  FCR METRIC UNITS , 2  FOR ENGLISH UNITS
  PROCFSS CODE NUMBER :-
         ISOBARIC    PROCESS   10
         ISOTHERMAL PFCCESS   20
         ISENTROPIC PROCESS   30
         ISOMETRIC  FFCCESS   40
         PCLYTRCPIC PFCCESS   50
         GENERAL     PRCCFSS  100
         E  X  I  T            0
  INITIAL STATE CF THE PROCESS ,
  FINAL STATE OF THE PROCESS : AND
  FLOW CONDITICN:-  1  FOR STEADY FLCW , 0  FCR NCN-FLCW

          1          10          3          4          1

    PLFASE ENTER THE CEVICE CCDF NUMBER :
 -----------------------------------------
 HEAT EXCHANGER: 1  , TURBINE: 2  , NCZZLE: 3  ,  CCMPRESSCR: 4  , CIFFLSER: 5
  PISTON: 6   , CTHERS: 7

         6

     YOU ENTERED THE FCLLCWING DATA :-
 ------------------------------------------------
    UNITS  OPTION        =   1
    PROCESS CCDE NUMBER =  10
    INITIAL STATE        =   3
    FINAL STATE          =   4
    FLOW CCNDITICN       =   1
    CEVICE CCDE NUMBER   =   6
 ------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

  SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =    5

 -------------------------------------------------------------------------
      IS IT AN ACIABATIC PROCESS ?
 **  PLEASE ENTER EITHER   YES  CR  NO
 -------------------------------------------------------------------------
N

 -------------------------------------------------------------------------
      IS THERE AN EXTERNAL WORK TERM ?
 **  PLEASE ENTER EITHER   YES  OR  NC
 -------------------------------------------------------------------------
N

*************************************************************************
 THE VALUES OF THE FOLLCWING CONSTANTS ARE STORED FOR YOU :-
  RU = 8.3150     SI UNIT       RU = 1545    ENGLISH UNIT
  G  = 9.80       SI UNIT       G  = 32.2    ENGLISH UNIT
  GC = 1.0        SI UNIT       GC = 32.2    ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUF OF EACH CCNSTANT REPLACE IT BY A PRCPER VALUE
*************************************************************************

    PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNCWN ENTER  C

  1.39999962

    PLEASE ENTER THE VALUE CF (24):CP , IF IT IS  UNKNCWN ENTER  0

  1.00380039
```

Figure 24. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLCWING ORCER  :-
    VARIABLE COCE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NC DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


         35   2.0CC0CCCO              4


      THE CATA YCU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      2.C00CC
   SUBSCRIPT            =      4
---------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

 Y


      DO YOU WANT TO ACC OR CHANGE CATA ?
 ***   TYPE IN EITHER   YES   CR   NC

N


      WOULD YOU LIKE TO SEE THE SCLUTICN PROCEDURE ?
 ***   TYPE IN EITHER   YES   CR   NC

N


                         *****  R E S U L T S  *****

PROCESS # = 3     PROCESS CODE # = 10    INITIAL STATE = 3     FINAL STATE = 4
---------------------------------------------------------------------------------------------
  1)        C.0           1.4000        1.0038        C.717C        C.2668        8.31

  2) ************ ************ ************      28.5923 ************ **********

  3)     663.4138     675.0527 ************       0.2918 ************     193.60

  4) ************     677.6182 ************     484.C129 ************ **********

  5) ************     484.0129 ************ ************ ************ **********

  6) ************ ************       C.0101 ************ ************       3.42

  7)     663.4138    1350.1055 ************       0.5837 ************     387.21

  8) ************    1355.2363 ************     568.C261 ************ **********

  9) ************     568.0261 ************ ************ ************ **********

 10) ************ ************       C.0201 ************ ************       1.71

 11) ************     193.6C49 ************ ************ ************ **********

 12) ************     193.6049 ************ ************ ************     484.C1

 13)        0.0          0.0           C.0           C.C       ************     677.61

 14) ************     677.6174 ************ ************ ************     484.01

 15) ************ ************ ************ ************ ************ **********

 16) ************ ************ ************ ************ ************       0.69

 17)        C.0       675.0522 ************       0.2918 ************     193.60

 18)       1.0000       2.0000       2.0000 ************ ************ **********

 19) ************ ************ ************ ************ ************ **********

 20) ************ ************ ************ ************ ************ **********
```

Figure 24. (Continued)

```
     DID YOL FCRGET TC ENTER CTHER CATA ?
 ***   TYPE IN EITHER  YES  OR  NO

N


     WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
 ***  TYPE IN EITHER  YES  CR  NC

N


    WOULD YCU LIKE TO SOLVE THE SAME PROCESS WITH
    NEW VALLES FCR SCME OF THE VARIABLES  ?
 ***  TYPE IN EITHER   YES   CR   NC

N


     WOULD YOU LIKE TC KEEP THE RESLLTS AND PROCEED
     TO SOLVE THE NEXT PRCCESS  ?
 ***  TYPE IN EITHER    YES   OR   NO

Y

   PLEASE ENTER : -
   ----------------
  UNITS OPTION:-  1  FCR METRIC UNITS , 2  FOR ENGLISH UNITS
  PROCESS CODE NUMBER :-
         ISOBARIC    PRCCESS   10
         ISOTHERMAL PRCCESS   20
         ISENTROPIC PRCCESS   30
         ISCMETRIC  PRCCESS   40
         PCLYTRCPIC PRCCESS   50
         GENERAL    PROCESS  100
         E  X  I  T            0
  INITIAL STATE CF THE PROCESS ,
  FINAL STATE OF THE PROCESS ; AND
  FLCW CONDITICN:-  1  FOR STEADY FLCW , 0  FOR NCN-FLCW

          1          3C          4          5          1

     PLEASE ENTER THE CEVICE CCDE NUMBER :
 ------------------------------------------
  HEAT EXCHANGER: 1  , TURBINE: 2  , NCZZLE: 3  ,  CCMPRESSCR: 4  , CIFFLSER: 5
   PISTON: 6  , CTHERS: 7

          6


     YOU ENTERED THE FCLLOWING DATA :-
 -------------------------------------------------
   UNITS  OPTICN        =   1
   PROCESS CODE NUMBER =  3C
   INITIAL STATE        =   4
   FINAL STATE          =   5
   FLOW CCNDITION       =   1
   DEVICE CCDE NUMBER   =   6
 -------------------------------------------------
 *** IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

  SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =    1C

 ---------------------------------------------------------------------------
     IS THERE AN EXTERNAL WORK TERM ?
 **  PLEASE ENTER EITHER  YES  CR  NC
 ---------------------------------------------------------------------------
N

###########################################################################
 THE VALUES OF THE FOLLOWING CCNSTANTS ARE STOREC FOR YCL :-
  RU = 8.3150     SI UNIT       RU = 1545   ENGLISH UNIT
  G  = 9.80       SI UNIT       G  = 32.2   ENGLISH UNIT
  GC = 1.0        SI UNIT       GC = 32.2   ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUE CF EACH CCNSTANT REPLACE IT BY A PRCPER VALUE
###########################################################################
```

Figure 24. (Continued)

```
     PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNOWN ENTER  0

   1.39999962

     PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0

   1.00380039

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

         35   1.50000000             5

    THE DATA YOU ENTERED ARE :-
-----------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      1.50000
   SUBSCRIPT            =      5
-----------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
 ***  TYPE IN EITHER  YES  OR  NO

N


                          *****  R E S U L T S  *****

 PROCESS # = 4     PROCESS CODE # = 30     INITIAL STATE = 4     FINAL STATE = 5
--------------------------------------------------------------------------------
  1)        1.4000       1.4000       1.0038       0.7170       0.2868        8.31

  2) ************ ************ ************      28.9923 ************ **********

  3)      663.4138    1350.1055 ************       0.5837 ************     367.21

  4) ************    1355.2363 ************     568.0261 ************ **********

  5) ************     568.0261 ************ ************ ************ **********

  6) ************ ************       0.0201 ************ ************       1.71

  7)      376.0596    1147.9719 ************       0.8755 ************     329.23

  8) ************    1152.3345 ************     823.0962 ************ **********

  9) ************     823.0962 ************ ************ ************ **********

 10) ************ ************       0.0302 ************ ************       1.14

 11) ************     144.9300 ************ ************ ************ **********

 12) ************     144.9300 ************ ************ ************    -144.93

 13)          0.0          0.0          0.0          0.0 ************    -202.90

 14)          0.0          0.0          0.0          0.0 ************    -144.93

 15) ************ ************ ************ ************ ************ **********
```

Figure 24. (Continued)

```
16) ************ ************ ************ ************        C.C         0.0
17)    -287.3542    -202.1338 ************       0.2918 ************    -57.57
18)       0.5669       C.8503       1.5000 ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********


    DID YOU FCRGET TC ENTER OTHER CATA ?
***   TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SEF THE RESULTS AGAIN ?
***  TYPE IN EITHER  YFS  CR  NO

N


   WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
   NEW VALUES FCR SCME OF THE VARIABLES  ?
***  TYPE IN EITHER   YES   OR   NC

N


    WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
    TO SOLVE THE NEXT PRCCESS  ?
***  TYPE IN EITHER    YES   OR   NO

Y

  PLEASE ENTER : -
 -----------------
 UNITS OPTION:-  1  FCR METRIC UNITS , 2  FOR ENGLISH UNITS
 PROCESS CODE NUMBER :-
         ISOBARIC    PROCESS   10
         ISOTHERMAL PROCESS   20
         ISENTROPIC PROCESS   30
         ISOMETRIC  PRCCESS   40
         POLYTROPIC PROCESS   50
         GENERAL    PROCESS  100
         E  X  I  T            0
 INITIAL STATE OF THE PROCESS ,
 FINAL STATE OF THE PRCCESS : AND
 FLOW CONDITICN:-  1  FOR STEADY FLOW , 0  FOR NON-FLOW

         1          40          5          1          1

   PLEASE ENTER THE DEVICE CODE NUMBER :
----------------------------------------
HEAT EXCHANGER: 1  , TURBINE: 2  , NOZZLE: 3  ,  COMPRESSOR: 4  , DIFFUSER: 5
 PISTON: 6  , OTHERS: 7

         6

    YOU ENTERED THE FOLLOWING DATA :-
-------------------------------------------------
  UNITS  OPTICN          =   1
  PROCESS CODE NUMBER =  40
  INITIAL STATE        =   5
  FINAL STATE          =   1
  FLOW CONDITION       =   1
  DEVICE CODE NUMBER  =   6
-------------------------------------------------
*** IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

 SUBSCRIPT OF ISENTROPIC  FINAL  STATE   =     6
```

Figure 24. (Continued)

```
-------------------------------------------------------------------------------
     IS IT AN ADIABATIC PROCESS ?
**  PLEASE ENTER EITHER   YES  OR  NO
-------------------------------------------------------------------------------
N

-------------------------------------------------------------------------------
     IS THERE AN EXTERNAL WORK TERM ?
**  PLEASE ENTER EITHER   YES  OR  NO
-------------------------------------------------------------------------------
N

*******************************************************************************
 THE VALUES OF THE FOLLOWING CONSTANTS ARE STORED FOR YOU :-
  RU = 8.3150     SI UNIT        RU = 1545   ENGLISH UNIT
  G  = 9.80       SI UNIT        G  = 32.2   ENGLISH UNIT
  GC = 1.0        SI UNIT        GC = 32.2   ENGLISH UNIT
 IF YOU LIKE TO CHANGE THE VALUE OF EACH CONSTANT REPLACE IT BY A PROPER VALUE
*******************************************************************************

     PLEASE ENTER THE VALUE OF (26):K , IF IT IS  UNKNOWN ENTER  0

   1.39999962

     PLEASE ENTER THE VALUE OF (24):CP , IF IT IS  UNKNOWN ENTER  0

   1.00380039

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


         34    .0                         1


     THE DATA YOU ENTERED ARE :-
-------------------------------------------------
   VARIABLE CODE NUMBER =     34
   VALUE                =      0.0
   SUBSCRIPT            =      1
-------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
***  TYPE IN EITHER  YES  OR  NO

N


    WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?
***  TYPE IN EITHER  YES  OR  NO

N
```

***** R E S U L T S *****

PROCESS # = 5   PROCESS CODE # = 40   INITIAL STATE = 5   FINAL STATE = 1

1)	************	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	376.0596	1147.9719	************	0.6755	************	329.23
4)	************	1152.3345	************	823.0962	************	**********
5)	************	823.0962	************	************	************	**********
6)	************	************	0.0302	************	************	1.14

Figure 24. (Continued)

```
 7)      95.0000     290.0000 ************       0.6755 ************      83.17
 8) ************     251.1021 ************     207.9301 ************ **********
 9) ************     207.9301 ************ ************ ************ **********
10) ************ ************       0.0302 ************ ************       1.14
11)        0.0          0.0          0.0          0.0   ************ **********
12)        0.0          0.0          0.0          0.0   ************    -615.16
13)        0.0          0.0          0.0          0.0   ************    -861.23
14) ************    -615.1660 ************ ************ ************    -615.16
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************ ************      -0.98
17)    -281.0596    -657.5719          0.0          0.0 ************    -246.06
18)       0.2526      .0.2526       1.0000 ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********


    DID YOU FORGET TO ENTER OTHER DATA ?
***   TYPE IN EITHER  YES  OR  NO

N

    WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?
***  TYPE IN EITHER  YES  OR  NO

N

    WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
***  TYPE IN EITHER   YES   OR   NO

N

     WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED
     TO SOLVE THE NEXT PROCESS  ?
***  TYPE IN EITHER    YES   OR   NO

N
------------------------------------------------------------------------------
                         C Y C L E   R E S U L T S
 INPUT HEAT/MASS =  836.9548          OUTPUT HEAT/MASS   =-1047.6578
 INPUT WORK/MASS = -114.7452          OUTPUT WORK/MASS   =  338.5349
 NET WORK / MASS =  223.7897          THERMAL EFFICIENCY =    0.2667
------------------------------------------------------------------------------

   WOULD YOU LIKE TO SOLVE THE SAME CYCLE WITH
   NEW VALUES FOR SOME OF THE VARIABLES  ?
***  TYPE IN EITHER  YES  OR  NO

Y

   PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
    PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

          1          2
```

Figure 24. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

         35   .166666667              2

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =     0.16667
   SUBSCRIPT            =     2
--------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

Y

    PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
     PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

          4          5

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

         35   3.00000000              5

     THE DATA YOU ENTERED ARE :-
--------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =     3.00000
   SUBSCRIPT            =     5
--------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

N


                         *****  R E S U L T S  *****

 PROCESS # = 1     PROCESS CODE # = 30     INITIAL STATE = 1     FINAL STATE = 2
--------------------------------------------------------------------------------
  1)      1.4000      1.4000      1.0338      0.7170      0.2668       8.31

  2) ************ ************ ************     28.5523 ************ **********

  3)     55.0000    290.0000 ************      0.8755 ************      83.17

  4) ************    291.1021 ************    207.9301 ************ **********

  5) ************    207.9301 ************ ************ ************ **********

  6) ************ ************      0.0302 ************ ************       1.14

  7)   1167.1707    593.8242 ************      0.1455 ************     170.30
```

Figure 24. (Continued)

8)	************	596.0808	************	425.7722	************	**********
9)	************	425.7722	************	************	************	**********
10)	************	************	0.0050	************	************	6.85
11)	************	-217.8421	************	************	************	**********
12)	************	-217.8421	************	************	************	217.84
13)	0.0	0.0	0.0	0.0	************	304.57
14)	0.0	0.0	0.0	0.0	************	217.84
15)	************	************	************	************	************	**********
16)	************	************	************	************	0.0	0.0
17)	1072.1707	203.8242	************	-0.7256	************	87.13
18)	12.2860	2.0477	0.1667	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 2 PROCESS CODE # = 40 INITIAL STATE = 2 FINAL STATE = 3

1)	************	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9523	************	**********
3)	1167.1707	553.8242	************	0.1459	************	170.30
4)	************	596.0808	************	425.7722	************	**********
5)	************	425.7722	************	************	************	**********
6)	************	************	0.0050	************	************	6.85
7)	1750.7559	850.7363	************	0.1459	************	255.46
8)	************	894.1213	************	638.6582	************	**********
9)	************	638.6582	************	************	************	**********
10)	************	************	0.0050	************	************	6.85
11)	0.0	0.0	0.0	0.0	************	**********
12)	0.0	0.0	0.0	0.0	************	212.86
13)	0.0	0.0	0.0	0.0	************	298.04
14)	************	212.8659	************	************	************	212.86
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.29
17)	583.5852	256.9119	0.0	0.0	************	85.15
18)	1.5000	1.5000	1.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

Figure 24. (Continued)

***** R E S U L T S *****

PROCESS # = 3   PROCESS CODE # = 10   INITIAL STATE = 3   FINAL STATE = 4

1)	0.0	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.5523	************	**********
3)	1750.7559	890.7363	************	0.1459	************	255.46
4)	************	894.1213	************	638.6582	************	**********
5)	************	638.6582	************	************	************	**********
6)	************	************	0.0050	************	************	6.85
7)	1750.7559	1781.4727	************	0.2918	************	510.92
8)	************	1788.2429	************	1277.3167	************	**********
9)	************	1277.3167	************	************	************	**********
10)	************	************	0.0101	************	************	3.42
11)	************	255.4630	************	************	************	**********
12)	************	255.4630	************	************	************	638.65
13)	0.0	0.0	0.0	0.8	************	894.12
14)	************	894.1208	************	************	************	638.65
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.69
17)	0.0	890.7361	************	0.1459	************	255.46
18)	1.0000	2.0000	2.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 4   PROCESS CODE # = 30   INITIAL STATE = 4   FINAL STATE = 5

1)	1.4000	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.5523	************	**********
3)	1750.7559	1781.4727	************	0.2918	************	510.92
4)	************	1788.2429	************	1277.3167	************	**********
5)	************	1277.3167	************	************	************	**********
6)	************	************	0.0101	************	************	3.42
7)	376.0593	1147.9712	************	0.8755	************	329.23
8)	************	1152.3337	************	823.0957	************	**********
9)	************	823.0957	************	************	************	**********
10)	************	************	0.0302	************	************	1.14
11)	************	454.2205	************	************	************	**********
12)	************	454.2205	************	************	************	-454.22
13)	0.0	0.0	0.0	0.8	************	-635.90
14)	0.0	0.0	0.0	0.8	************	-454.22

Figure 24. (Continued)

15)	************	************	************	************	************	**********
16)	************	************	************	************	0.0	0.0
17)	-1374.6965	-633.5010	************	0.5837	************	-181.66
18)	0.2148	0.6444	3.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 5 PROCESS CODE # = 40 INITIAL STATE = 5 FINAL STATE = 1

1)	************	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	376.0593	1147.9712	************	0.6755	************	329.23
4)	************	1152.3337	************	823.0957	************	**********
5)	************	823.0957	************	************	************	**********
6)	************	************	0.0302	************	************	1.14
7)	95.0000	290.0000	************	0.6755	************	83.17
8)	************	291.1021	************	207.9301	************	**********
9)	************	207.9301	************	************	************	**********
10)	************	************	0.0302	************	************	1.14
11)	0.0	0.0	0.0	0.0	************	**********
12)	0.0	0.0	0.0	0.0	************	-615.16
13)	0.0	0.0	0.0	0.0	************	-861.23
14)	************	-615.1655	************	************	************	-615.16
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	-0.96
17)	-281.0593	-857.9712	0.0	0.0	************	-246.06
18)	0.2526	0.2526	1.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

C Y C L E R E S U L T S

```
INPUT HEAT/MASS = 1107.0066        OUTPUT HEAT/MASS   =-1047.6573
INPUT WORK/MASS = -217.8421        OUTPUT WORK/MASS   =  709.6833
NET WORK / MASS =  491.8411        THERMAL EFFICIENCY =    0.4443
```

```
    WOULD YOU LIKE TO SOLVE THE SAME CYCLE WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
***  TYPE IN EITHER  YES  OR  NO

Y

    PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
     PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

          1            2
```

Figure 24. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          35   .1111111C4             2

      THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      0.11111
   SUBSCRIPT            =      2
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

Y

    PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
     PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

          4            5

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          35   4.50000C03             5

      THE DATA YOU ENTERED ARE :-
---------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      4.50000
   SUBSCRIPT            =      5
---------------------------------------------------
***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y

     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

N

                    *****  R E S U L T S  *****

PROCESS # = 1    PROCESS CODE # = 30    INITIAL STATE = 1    FINAL STATE = 2
-------------------------------------------------------------------------------
 1)       1.4000      1.4000      1.0038      0.7170      0.2868       8.31

 2) ************ ************ ************   28.9923 ************ **********

 3)      95.0000    290.0000 ************      0.8755 ************    83.17

 4) ************    291.1021 ************    207.9331 ************ **********

 5) ************    207.9331 ************ ************ ************ **********

 6) ************ ************      0.0302 ************ ************     1.14

 7)    2055.0281    658.3843 ************      0.0573 ************   200.29
```

Figure 24. (Continued)

8)	************	701.0383	************	500.7417	************	**********
9)	************	500.7417	************	************	************	**********
10)	************	************	0.0034	************	************	10.27
11)	************	-292.8115	************	************	************	**********
12)	************	-292.8115	************	************	************	292.81
13)	0.0	0.0	0.0	0.0	************	409.93
14)	0.0	0.0	0.0	0.0	************	292.81
15)	************	************	************	************	************	**********
16)	************	************	************	************	0.0	0.0
17)	1964.0281	408.3843	************	-0.7782	************	117.12
18)	21.6740	2.4282	0.1111	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 2   PROCESS CODE # = 40   INITIAL STATE = 2   FINAL STATE = 3

1)	************	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	2059.0281	658.3843	************	0.0573	************	200.29
4)	************	701.0383	************	500.7417	************	**********
5)	************	500.7417	************	************	************	**********
6)	************	************	0.0034	************	************	10.27
7)	3388.5420	1047.5764	************	0.0573	************	300.44
8)	************	1051.5576	************	751.1125	************	**********
9)	************	751.1125	************	************	************	**********
10)	************	************	0.0034	************	************	10.27
11)	0.0	0.0	0.0	0.0	************	**********
12)	0.0	0.0	0.0	0.0	************	250.37
13)	0.0	0.0	0.0	0.0	************	350.51
14)	************	250.3702	************	************	************	250.37
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.29
17)	1025.5139	349.1912	0.0	0.0	************	100.14
18)	1.5000	1.5000	1.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

Figure 24. (Continued)

***** R E S U L T S *****

PROCESS # = 3 PROCESS CODE # = 10 INITIAL STATE = 3 FINAL STATE = 4

1)	0.0	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	3288.5420	1047.5764	************	0.0973	************	300.44
4)	************	1051.5576	************	751.1125	************	**********
5)	************	751.1125	************	************	************	**********
6)	************	************	0.0034	************	************	10.27
7)	3288.5420	2095.1528	************	0.1946	************	600.88
8)	************	2103.1152	************	1502.2253	************	**********
9)	************	1502.2253	************	************	************	**********
10)	************	************	0.0067	************	************	5.13
11)	************	300.4448	************	************	************	**********
12)	************	300.4448	************	************	************	751.11
13)	0.0	0.0	0.0	0.0	************	1051.55
14)	************	1051.5579	************	************	************	751.11
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.69
17)	0.0	1047.5771	************	0.0973	************	300.44
18)	1.0000	2.0000	2.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 4 PROCESS CODE # = 30 INITIAL STATE = 4 FINAL STATE = 5

1)	1.4000	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	3288.5420	2095.1528	************	0.1946	************	600.88
4)	************	2103.1152	************	1502.2253	************	**********
5)	************	1502.2253	************	************	************	**********
6)	************	************	0.0067	************	************	5.13
7)	376.0596	1147.9714	************	0.6755	************	329.23
8)	************	1152.3340	************	823.0959	************	**********
9)	************	823.0959	************	************	************	**********
10)	************	************	0.0302	************	************	1.14
11)	************	679.1292	************	************	************	**********
12)	************	679.1292	************	************	************	-679.12
13)	0.0	0.0	0.0	0.0	************	-950.78
14)	0.0	0.0	0.0	0.0	************	-679.12

Figure 24. (Continued)

```
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************        C.C          0.0
17)   -2712.4824   -547.1812 ************       0.ECCS ************    -271.65
18)       C.1218      0.5479       4.5000 ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********


                         ***** R E S U L T S *****

PROCESS # = 5      PRCCESS CODE # = 40     INITIAL STATE = 5     FINAL STATE = 1
--------------------------------------------------------------------------------
 1) ************       1.4003       1.0038       0.7170       C.2868        8.31
 2) ************ ************ ************      28.5523 ************ **********
 3)     376.0596    1147.9714 ************       0.E755 ************      329.23
 4) ************    1152.3340 ************     823.C559 ************ **********
 5) ************     823.0559 ************ ************ ************ **********
 6) ************ ************       C.0302 ************ ************        1.14
 7)      95.0C0C     290.0000 ************       0.E755 ************       83.17
 8) ************     291.1021 ************     207.53C1 ************ **********
 9) ************     2C7.9301 ************ ************ ************ **********
10) ************ ************       C.0302 ************ ************        1.14
11)          0.0          0.0          C.0          0.C ************ **********
12)          C.0          0.0          C.0          0.0 ************     -615.16
13)          0.0          0.0          C.0          0.0 ************     -861.23
14) ************   -615.1658 ************ ************ ************     -615.16
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************ ************       -0.98
17)    -281.0596   -857.9714          C.0          0.0 ************     -246.06
18)       0.2526       0.2526       1.0000 ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********

--------------------------------------------------------------------------------
                         C Y C L E   R E S U L T S
INPUT HEAT/MASS = 1301.9280          OUTPUT HEAT/MASS    = -615.1658
INPUT WORK/MASS = -292.8115          OUTPUT WORK/MASS    =  979.5740
NET WORK / MASS =  686.7625          THERMAL EFFICIENCY  =    0.5275
--------------------------------------------------------------------------------

   WOULD YCU LIKE TO SOLVE THE SAME CYCLE WITH
   NEW VALUES FCR SCME OF THE VARIABLES  ?
***  TYPE IN EITHER  YES  CR  NO

Y

   PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
    PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

        1           2
```

Figure 24. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

          35   .833333135E-01          2

      THE DATA YOU ENTERED ARE :-
 ---------------------------------------------------
    VARIABLE CODE NUMBER =     35
    VALUE                =      0.08333
    SUBSCRIPT            =      2
 ---------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

 Y

     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

 Y

    PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
     PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

          4          5

*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

        35   6.00000000              5

     THE DATA YOU ENTERED ARE :-
 ---------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      6.00000
   SUBSCRIPT            =      5
 ---------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

 Y

    DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

 N

                          *****  R E S U L T S  *****

 PROCESS # = 1    PROCESS CODE # = 30    INITIAL STATE = 1    FINAL STATE = 2
 ------------------------------------------------------------------------------
  1)      1.4000      1.4000      1.0058       0.7170      0.2868       6.31
  2) ************ ************ ************   28.5523 ************ **********
  3)     55.0000    250.0000 ************      0.6755 ************      83.17
  4) ************    291.1021 ************   207.9301 ************ **********
  5) ************    207.9301 ************ ************ ************ **********
  6) ************ ************      0.0302 ************ ************       1.14
  7)   3080.1838    763.5557 ************      0.0730 ************     224.72
```

Figure 24. (Continued)

8)	************	786.5334	************	561.8096	************	**********
9)	************	561.8096	************	************	************	**********
10)	************	************	0.0025	************	************	13.70
11)	************	-353.8794	************	************	************	**********
12)	************	-353.8794	************	************	************	353.87
13)	0.0	0.0	0.0	0.0	************	495.43
14)	0.0	0.0	0.0	0.0	************	353.87
15)	************	************	************	************	************	**********
16)	************	************	************	************	0.0	0.0
17)	2985.1838	493.5554	************	-0.8025	************	141.55
18)	32.4230	2.7019	0.0833	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 2   PROCESS CODE # = 40   INITIAL STATE = 2   FINAL STATE = 3

1)	************	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	3380.1838	783.5557	************	0.0730	************	224.72
4)	************	786.5334	************	561.8096	************	**********
5)	************	561.8096	************	************	************	**********
6)	************	************	0.0025	************	************	13.70
7)	4620.2734	1175.3335	************	0.0730	************	337.08
8)	************	1179.8003	************	842.7146	************	**********
9)	************	842.7146	************	************	************	**********
10)	************	************	0.0025	************	************	13.70
11)	0.0	0.0	0.0	0.0	************	**********
12)	0.0	0.0	0.0	0.0	************	280.90
13)	0.0	0.0	0.0	0.0	************	393.26
14)	************	280.9038	************	************	************	280.90
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.29
17)	1540.0896	251.7766	0.0	0.0	************	112.36
18)	1.5000	1.5000	1.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

Figure 24. (Continued)

***** R E S U L T S *****

PROCESS # = 3 PROCESS CODE # = 10 INITIAL STATE = 3 FINAL STATE = 4

1)	0.0	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.5523	************	**********
3)	4620.2734	1175.3335	************	0.0730	************	337.08
4)	************	1179.8000	************	842.7146	************	**********
5)	************	842.7146	************	************	************	**********
6)	************	************	0.0025	************	************	13.70
7)	4620.2734	2350.6670	************	0.1459	************	674.17
8)	************	2359.6003	************	1685.4292	************	**********
9)	************	1685.4292	************	************	************	**********
10)	************	************	0.0050	************	************	6.85
11)	************	337.0852	************	************	************	**********
12)	************	337.0852	************	************	************	842.71
13)	0.0	0.0	0.0	0.0	************	1179.80
14)	************	1179.7998	************	************	************	842.71
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.69
17)	0.0	1175.3335	************	0.0730	************	337.08
18)	1.0000	2.0000	2.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 4 PROCESS CODE # = 30 INITIAL STATE = 4 FINAL STATE = 5

1)	1.4000	1.4000	1.0038	0.7170	0.2868	6.31
2)	************	************	************	28.5523	************	**********
3)	4620.2734	2350.6670	************	0.1459	************	674.17
4)	************	2359.6003	************	1685.4292	************	**********
5)	************	1685.4292	************	************	************	**********
6)	************	************	0.0050	************	************	6.85
7)	376.0591	1147.9712	************	0.8755	************	329.23
8)	************	1152.3337	************	823.0957	************	**********
9)	************	823.0957	************	************	************	**********
10)	************	************	0.0302	************	************	1.14
11)	************	862.3337	************	************	************	**********
12)	************	862.3337	************	************	************	-862.33
13)	0.0	0.0	0.0	0.0	************	-1207.26
14)	0.0	0.0	0.0	0.0	************	-862.33

Figure 24. (Continued)

```
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************        0.0          0.0
17)   -4244.2109   -1202.6963 ************       0.7256 ************    -344.93
18)       0.0814       0.4884       6.0000 ************ ************ **********
20) ************ ************ ************ ************ ************ **********


                      *****  R E S U L T S  *****
PROCESS # = 5      PROCESS CODE # = 40      INITIAL STATE = 5      FINAL STATE = 1
-------------------------------------------------------------------------------
 1) ************       1.4000       1.0038       0.7170       0.2868       8.31
 2) ************ ************ ************      28.9923 ************ **********
 3)     376.0591    1147.9712 ************       0.8755 ************     329.23
 4) ************    1152.3337 ************     823.0957 ************ **********
 5) ************     823.0957 ************ ************ ************ **********
 6) ************ ************       0.0302 ************ ************       1.14
 7)      95.0000     290.0000 ************       0.8755 ************      83.17
 8) ************     291.1021 ************     207.9301 ************ **********
 9) ************     207.9301 ************ ************ ************ **********
10) ************ ************       0.0302 ************ ************       1.14
11)          0.0          0.0          0.0          0.0 ************ **********
12)          0.0          0.0          0.0          0.0 ************    -615.16
13)          0.0          0.0          0.0          0.0 ************    -861.23
14) ************    -615.1655 ************ ************ ************    -615.16
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************ ************      -0.98
17)    -281.0591    -857.9712          0.0          0.0 ************    -240.06
18)       0.2526       0.2526       1.0000 ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********

-------------------------------------------------------------------------------
                       C Y C L E   R E S U L T S

INPUT HEAT/MASS = 1460.7036          OUTPUT HEAT/MASS    = -615.1655
INPUT WORK/MASS = -353.3794          OUTPUT WORK/MASS    = 1199.4189
NET WORK / MASS =  845.5396          THERMAL EFFICIENCY =    0.5789
-------------------------------------------------------------------------------

    WOULD YOU LIKE TO SOLVE THE SAME CYCLE WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
 ***  TYPE IN EITHER  YES  OR  NO

Y

    PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
     PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

         1           2
```

Figure 24. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          35   .666666627E-01            2


     THE DATA YOU ENTERED ARE :-
------------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      0.06667
   SUBSCRIPT            =      2
------------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

Y

    PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
     PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

          4          5


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : C  C  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          35   7.5CCCCC00               5


     THE DATA YOU ENTERED ARE :-
------------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      7.50000
   SUBSCRIPT            =      5
------------------------------------------------------
 ***IF OK , TYPE IN YES, IF NOT TYPE IN NO

Y


    DO YOU WANT TO ADD OR CHANGE DATA ?
 ***  TYPE IN EITHER  YES  OR  NO

N


                  *****  R E S U L T S  *****

PROCESS # = 1     PROCESS CODE # = 30     INITIAL STATE = 1     FINAL STATE = 2
```

1)	1.4000	1.4000	1.0038	0.7170	C.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	95.0000	290.0000	************	0.8755	************	83.17
4)	************	291.1021	************	207.9301	************	**********
5)	************	207.9301	************	************	************	**********
6)	************	************	C.0302	************	************	1.14
7)	4209.6914	856.7097	************	0.C5E4	************	245.70

Figure 24. (Continued)

8)	************	659.9653	************	614.2612	************	**********
9)	************	614.2612	************	************	************	**********
10)	************	************	0.0020	************	************	17.13
11)	************	-406.3311	************	************	************	**********
12)	************	-406.3311	************	************	************	406.33
13)	0.0	0.0	0.0	0.0	************	568.86
14)	0.0	0.0	0.0	0.0	************	406.33
15)	************	************	************	************	************	**********
16)	************	************	************	************	0.0	0.0
17)	-114.6914	566.7097	************	-0.8171	************	162.53
18)	44.3126	2.9542	0.0667	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 2   PROCESS CODE # = 40   INITIAL STATE = 2   FINAL STATE = 3

1)	************	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9523	************	**********
3)	4209.6914	856.7097	************	0.0584	************	245.70
4)	************	659.9653	************	614.2612	************	**********
5)	************	614.2612	************	************	************	**********
6)	************	************	0.0020	************	************	17.13
7)	6314.5352	1285.0645	************	0.0584	************	368.55
8)	************	1289.9480	************	921.3916	************	**********
9)	************	921.3916	************	************	************	**********
10)	************	************	0.0020	************	************	17.13
11)	0.0	0.0	0.0	0.0	************	**********
12)	0.0	0.0	0.0	0.0	************	307.12
13)	0.0	0.0	0.0	0.0	************	429.98
14)	************	307.1296	************	************	************	307.12
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.29
17)	2104.8437	428.3538	0.0	0.0	************	122.85
18)	1.5000	1.5000	1.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

Figure 24. (Continued)

***** R E S U L T S *****

PROCESS # = 3 PROCESS CODE # = 10 INITIAL STATE = 3 FINAL STATE = 4

1)	C.0	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	6314.5352	1285.0645	************	0.0584	************	368.55
4)	************	1289.9480	************	921.3916	************	**********
5)	************	921.3916	************	************	************	**********
6)	************	************	C.0020	************	************	17.13
7)	6314.5352	2570.1289	************	0.1167	************	737.11
8)	************	2579.8962	************	1842.7834	************	**********
9)	************	1842.7834	************	************	************	**********
10)	************	************	C.0040	************	************	8.56
11)	************	368.5562	************	************	************	**********
12)	************	368.5562	************	************	************	921.39
13)	C.0	0.0	C.0	0.C	************	1289.94
14)	************	1289.9478	************	************	************	921.39
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.69
17)	0.0	1285.0645	************	C.C584	************	368.55
18)	1.0000	2.0000	2.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 4 PROCESS CODE # = 30 INITIAL STATE = 4 FINAL STATE = 5

1)	1.4000	1.4000	1.0038	0.7170	C.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	6314.5352	2570.1289	************	0.1167	************	737.11
4)	************	2579.8962	************	1842.7834	************	**********
5)	************	1842.7834	************	************	************	**********
6)	************	************	C.0040	************	************	8.56
7)	376.0591	1147.9707	************	C.8755	************	329.23
8)	************	1152.3333	************	823.0555	************	**********
9)	************	823.0555	************	************	************	**********
10)	************	************	C.0302	************	************	1.14
11)	************	1019.6875	************	************	************	**********
12)	************	1019.6875	************	************	************	-1019.68
13)	C.0	0.0	C.0	0.0	************	-1427.56
14)	C.0	0.0	C.0	0.C	************	-1019.68

Figure 24. (Continued)

```
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************        C.C        0.0
17)   -5938.4727   -1422.1577 ************       0.7588 ************    -407.87
18)       0.0596       0.4467       7.5000 ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********


                         ***** R E S U L T S *****

PROCESS # = 5     PROCESS CODE # = 40     INITIAL STATE = 5     FINAL STATE = 1
--------------------------------------------------------------------------------
 1) ************       1.4000       1.0038       0.7170       C.2868       8.31
 2) ************ ************ ************      28.5523 ************ **********
 3)     376.0591    1147.9707 ************       0.6755 ************     329.23
 4) ************    1152.3333 ************     823.0555 ************ **********
 5) ************     823.0555 ************ ************ ************ **********
 6) ************ ************       C.0302 ************ ************       1.14
 7)      95.0000     290.0000 ************       C.6755 ************      83.17
 8) ************     291.1021 ************     207.9301 ************ **********
 9) ************     207.9301 ************ ************ ************ **********
10) ************ ************       C.0302 ************ ************       1.14
11)          0.0          0.0          C.0          0.C ************ **********
12)          0.0          0.0          C.0          0.C ************    -615.16
13)          C.0          0.0          0.0          0.0 ************    -861.23
14) ************    -615.1653 ************ ************ ************    -615.16
15) ************ ************ ************ ************ ************ **********
16) ************ ************ ************ ************ ************      -0.98
17)    -281.0591    -857.9707          C.0          0.C ************    -246.06
18)       0.2526       0.2526       1.0000 ************ ************ **********
19) ************ ************ ************ ************ ************ **********
20) ************ ************ ************ ************ ************ **********

--------------------------------------------------------------------------------
                        C Y C L E   R E S U L T S

INPUT HEAT/MASS = 1597.0774          OUTPUT HEAT/MASS   = -615.1653
INPUT WORK/MASS = -406.3311          OUTPUT WORK/MASS   = 1388.2437
NET WORK / MASS =  981.9126          THERMAL EFFICIENCY =    C.6148
--------------------------------------------------------------------------------

   WOULD YOU LIKE TO SOLVE THE SAME CYCLE WITH
   NEW VALUES FOR SOME OF THE VARIABLES  ?
***  TYPE IN EITHER  YES  OR  NO

Y

   PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
    PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

         1          2
```

Figure 24. (Continued)

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          35   .555555C01E-01          2

     THE DATA YOU ENTERED ARE :-
-----------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      0.05556
   SUBSCRIPT            =     2
-----------------------------------------------------
 ***IF OK , TYPE IN YES. IF NOT TYPE IN NO

Y


     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***   TYPE IN EITHER  YES  OR  NO

Y

    PLEASE ENTER THE INITAIL AND FINAL STATES OF THE
     PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH

          4           5


*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
    NOW , PLEASE ENTER THE REST OF THE DATA OR THE NEW VALUES
    IN THE FOLLOWING ORDER  :-
    VARIABLE CODE NUMBER   ,  VALUE   ,  AND SUBSCRIPT
    IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*


          35   9.00000000              5

     THE DATA YOU ENTERED ARE :-
-----------------------------------------------------
   VARIABLE CODE NUMBER =     35
   VALUE                =      9.00000
   SUBSCRIPT            =     5
-----------------------------------------------------
 ***IF OK , TYPE IN YES. IF NOT TYPE IN NO

Y


     DO YOU WANT TO ADD OR CHANGE DATA ?
 ***   TYPE IN EITHER  YES  OR  NO

N


                        *****  R E S U L T S  *****

 PROCESS # = 1     PROCESS CODE # = 30     INITIAL STATE = 1     FINAL STATE = 2
-------------------------------------------------------------------------------
  1)       1.4000       1.4000       1.0038       0.7170       0.2868       8.31

  2) ************ ************ ************      28.5923 ************ **********

  3)      95.0000     290.0000 ************       0.8755 ************      83.17

  4) ************     291.1021 ************     207.9301 ************ **********

  5) ************     207.9301 ************ ************ ************ **********

  6) ************ ************       0.0302 ************ ************       1.14

  7)    5433.8086     521.5279 ************       0.0400 ************     264.29
```

Figure 24. (Continued)

8)	************	925.0249	************	660.7322	************	**********
9)	************	660.7322	************	************	************	**********
10)	************	************	0.0017	************	************	20.55
11)	************	-452.8020	************	************	************	**********
12)	************	-452.8027	************	************	************	452.80
13)	0.0	0.0	0.0	0.0	************	635.92
14)	0.0	0.0	0.0	0.0	************	452.80
15)	************	************	************	************	************	**********
16)	************	************	************	************	0.0	0.0
17)	5338.8086	921.5227	************	-0.8269	************	181.12
18)	57.1980	3.1777	0.0556	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 2 PROCESS CODE # = 40 INITIAL STATE = 2 FINAL STATE = 3

1)	************	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	5433.8086	921.5229	************	0.0486	************	264.29
4)	************	925.0249	************	660.7322	************	**********
5)	************	660.7322	************	************	************	**********
6)	************	************	0.0017	************	************	20.55
7)	8150.7109	1382.2844	************	0.0486	************	396.43
8)	************	1387.5376	************	991.0984	************	**********
9)	************	991.0984	************	************	************	**********
10)	************	************	0.0017	************	************	20.55
11)	0.0	0.0	0.0	0.0	************	**********
12)	0.0	0.0	0.0	0.0	************	330.36
13)	0.0	0.0	0.0	0.0	************	462.51
14)	************	330.3652	************	************	************	330.36
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.29
17)	2716.9023	460.7605	0.0	0.0	************	132.14
18)	1.5000	1.5000	1.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

Figure 24. (Continued)

***** R E S U L T S *****

PROCESS # = 3 PROCESS CODE # = 10 INITIAL STATE = 3 FINAL STATE = 4

1)	0.0	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	8150.7109	1382.2844	************	0.0486	************	396.43
4)	************	1387.5376	************	991.0984	************	**********
5)	************	991.0984	************	************	************	**********
6)	************	************	0.0017	************	************	20.55
7)	8150.7109	2764.5688	************	0.0573	************	792.87
8)	************	2775.0752	************	1982.1970	************	**********
9)	************	1982.1970	************	************	************	**********
10)	************	************	0.0034	************	************	10.27
11)	************	396.4387	************	************	************	**********
12)	************	396.4387	************	************	************	991.09
13)	0.0	0.0	0.0	0.0	************	1387.53
14)	************	1387.5371	************	************	************	991.09
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	0.69
17)	0.0	1382.2844	************	0.0486	************	396.43
18)	1.0000	2.0000	2.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 4 PROCESS CODE # = 30 INITIAL STATE = 4 FINAL STATE = 5

1)	1.4000	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.9923	************	**********
3)	8150.7109	2764.5688	************	0.0573	************	792.87
4)	************	2775.0752	************	1982.1970	************	**********
5)	************	1982.1970	************	************	************	**********
6)	************	************	0.0034	************	************	10.27
7)	376.0596	1147.9707	************	0.8755	************	329.23
8)	************	1152.3233	************	823.0955	************	**********
9)	************	823.0955	************	************	************	**********
10)	************	************	0.0302	************	************	1.14
11)	************	1159.1008	************	************	************	**********
12)	************	1159.1008	************	************	************	-1159.10
13)	0.0	0.0	0.0	0.0	************	-1622.74
14)	0.0	0.0	0.0	0.0	************	-1159.10
15)	************	************	************	************	************	**********

Figure 24. (Continued)

16)	************	************	************	************	0.0	0.0
17)	-7774.6484	-1616.5574	************	0.7782	************	-463.63
18)	0.0461	0.4152	5.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

***** R E S U L T S *****

PROCESS # = 5 PROCESS CODE # = 40 INITIAL STATE = 5 FINAL STATE = 1

1)	************	1.4000	1.0038	0.7170	0.2868	8.31
2)	************	************	************	28.5523	************	**********
3)	376.0556	1147.5707	************	0.8755	************	329.23
4)	************	1152.3333	************	823.0555	************	**********
5)	************	823.0955	************	************	************	**********
6)	************	************	0.0302	************	************	1.14
7)	95.0000	290.0000	************	0.8755	************	83.17
8)	************	291.1321	************	207.5301	************	**********
9)	************	207.9301	************	************	************	**********
10)	************	************	0.0302	************	************	1.14
11)	0.0	0.0	0.0	0.0	************	**********
12)	0.0	0.0	0.0	0.0	************	-615.16
13)	0.0	0.0	0.0	0.0	************	-861.23
14)	************	-615.1653	************	************	************	-615.16
15)	************	************	************	************	************	**********
16)	************	************	************	************	************	-0.98
17)	-281.0556	-857.5707	0.0	0.0	************	-246.06
18)	0.2526	0.2526	1.0000	************	************	**********
19)	************	************	************	************	************	**********
20)	************	************	************	************	************	**********

Figure 24. (Continued)

```
--------------------------------------------------------------------------------
                         C Y C L E   R E S U L T S

 INPUT HEAT/MASS = 1717.9323          OUTPUT HEAT/MASS   = -615.1653
 INPUT WORK/MASS = -452.8020          OUTPUT WORK/MASS   = 1555.5396
 NET WORK / MASS = 1102.7375          THERMAL EFFICIENCY =    0.6419
--------------------------------------------------------------------------------


    WOULD YOU LIKE TO SOLVE THE SAME CYCLE WITH
    NEW VALUES FOR SOME OF THE VARIABLES  ?
 ***  TYPE IN EITHER  YES  OR  NO

NO

################################################################################
  WOULD YOU LIKE TO SOLVE A NEW PROBLEM ?
 *** TYPE IN EITHER    YES   OR   NO
################################################################################

NO


********************************************************************************
*************************   S E E   Y O U   L A T E R   ************************
********************************************************************************
```

Figure 24. (Continued)

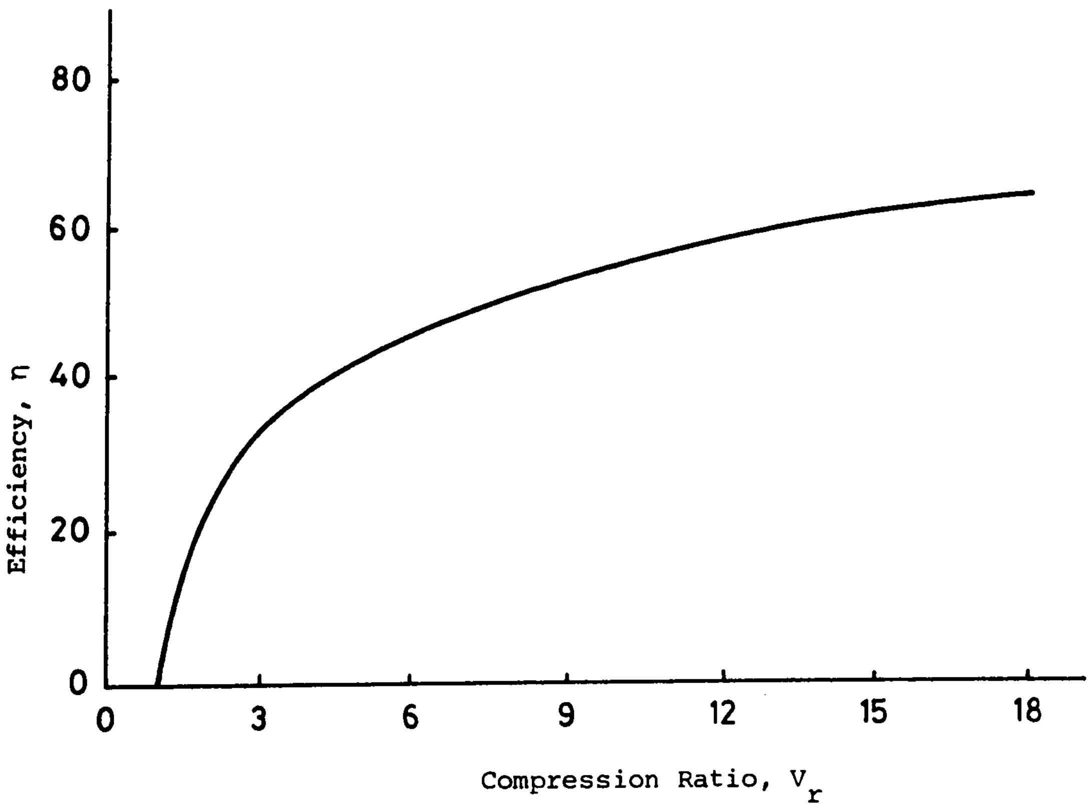


Figure 25. Dual Cycle Compression Ratio vs Efficiency in Example 6

13. DISCUSSIONS AND CONCLUSIONS

By now, we have gone through the various aspects of the computer program and the application of it by using the illustrated examples.

Engineering education is evolving constantly in a dynamic process to keep up with new innovations being introduced into technical areas. Applications of the computer have appeared in every discipline of engineering design and training since it became available. The technique presented in this thesis is intended, obviously, to improve the understanding of engineering thermodynamics with the aid of a computer. The objective can be accomplished in two ways:

(A) Greater motivation instilled in students:

The use of an interactive mode computer-assisted technique will develop greater motivation in students using the program. Students who are bashful or afraid of seeking their instructor's help can use the aid of the program to assist and to improve their understanding of the subject of engineering thermodynamics.

(B) More cases can be tested:

The availability of the program would allow and encourage more cases to be tested by instructors as well as students.

For example, parametric studies involving the dual cycle thermal efficiency versus compression ratio or any other parameter can be carried out easily with the aid of the program as shown in the last example without going through many repetitive manual calculations. This type of study would certainly enhance their understanding and appreciation of the subject matter.

The technique developed here for directing the program through only applicable equations may readily be extended to include some parameters of equations that the initial assumptions have excluded, and may also be of use in disciplines other than thermodynamics.

Further, if the program could in turn be coupled with a program that manipulates Steam Tables data, then the program could be modified to handle problems involving two-phase systems.

Finally, it must be pointed out that although the program as presented can be used to solve a great variety of problems. Certainly, there are problems which can not be handled by this program as it is presently structured. The objective of the computer-assisted technique, therefore, is to assist the beginners in learning and to encourage those experienced in the field to go beyond normal problem solving routine into creative design studies.

A final statement is now in order. Man must think, the computer must work according to its master. Let the computer assist man!

14. LIST OF REFERENCES

1 Stagg, Glenn, W., and El-Abiad, Ahmed H., "Computer Methods in Power System Analysis", McGraw-Hill, New York, 1968.

2 Streeter, Victor L., and Wylie, E.Benjamin, "Hydraulic Transients", McGraw-Hill, New York, 2nd Edition, 1972.

3 Streeter, Victor L., and Wylie, E. Benjamin, "Fluid Mechanics", McGraw-Hill, Kogakusha Ltd., International Student Edition, 6th Edition, 1975.

4 Adams, J. Alan, and Rogers, David F., "Computer Aided Heat Transfer Analysis", McGraw-Hill, New York, 1973.

5 Isenhour, Thomas L., and Jurs, Peter C., "Introduction to Computer Programming for Chemists", Allyn and Bacon, Inc., Boston, 1972.

6 Mattson, James S., Mark, Harry B., Jr., and MacDonald, Hubert C., Jr., "Computer-Assisted Instruction in Chemistry", Part B: Applications, Marcel Dekker, Inc., New York, 1974.

7 Motard, R.L., and Lee, H.M., "CHESS: Chemical Engineering Simulation System", User's Guide, University of Houston, Houston, Texas, 3rd Edition, Copyright 1971.

8 Hunter, Stephen, E., "A Computer-Aided Method for Thermodynamics Analysis", M.S.Thesis, Portland State University, Portland, Oregon, U.S.A., August 1977, pp. 1-126.

9 Van Wylen, Gordon, J., and Sonntag, Richard E., "Fundamental of Classical Thermodynamics", John Wiley and Sons, Inc., New York, 2nd Edition, S.I.Version, 1976.

10 Chen, P.I., Al-Farayedhi, A.A., " A Computer-Aided Instruction in Thermodynamics", Proceedings, Fifth National Computer Conference, pp.155-174 , Dhahran, Saudi Arabia, 1978.

11 Huang, Francis F., "Engineering Thermodynamics", McMillan Publishing Co., Inc., New York, Collier MacMillan International Edition, 1976.

12 Wark, Kenneth, "Thermodynamics", McGraw-Hill Book Company, New York, 3rd Edition, 1977.

APPENDIX A. The Description of Input Variables

VARIABLE	CODE NUMBER	UNITS OPTION		SUBSCRIPT		
		SI (1)	ENGLISH (2)	I	F	S
A	76	m^2	ft^2	√	√	√
A_r	97	-	-		√	√
c_p	24	KJ/Kg°K	ft.lb/lbm°R	√		
c_v	25	"	"	√		
CPLTR	60	"	"		√	√
CPLVR	61	"	"		√	√
CVLPR	62	"	"		√	√
CVLTR	59	"	"		√	√
CVLVR	63	"	"		√	√
E	18	KJ	ft.lb	√	√	√
ΔE	48	"	"		√	√
$\dot{E}$	80	KW	ft.lb/S	√	√	√
$\Delta\dot{E}$	86	"	"		√	√
e	19	KJ/Kg	ft.lb/lbm	√	√	√
Δe	49	"	"		√	√
$\dot{e}$	81	KW/Kg	ft.lb/lbm.S	√	√	√

APPENDIX A. (Continued)

VARIABLE	CODE NUMBER	UNITS OPTION		SUBSCRIPT		
		SI (1)	ENGLISH (2)	I	F	S
$\Delta\dot{e}$	87	KW/Kg	ft.lb/lbm.s		✓	✓
g	32	m/s^2	ft/s^2	✓		
g_c	98	-	ft.lbm/lb.s	✓		
H	8	KJ	ft.lb	✓	✓	✓
ΔH	42	"	"		✓	✓
h	9	KJ/Kg	ft.lb/lbm	✓	✓	✓
Δh	43	"	"		✓	✓
K	26	-	-	✓		
KE	16	KJ	ft.lb	✓	✓	✓
ΔKE	50	"	"		✓	✓
ke	17	KJ/Kg	ft.lb/lbm	✓	✓	✓
Δke	51	"	"		✓	✓
LPR	54	-	-		✓	✓
LTR	55	-	-		✓	✓
LVR	56	-	-		✓	✓
M	28	Kg/Kg.mole	lbm/lbm.mole	✓		

VARIABLE	CODE NUMBER	UNITS OPTION		SUBSCRIPT		
		SI (1)	ENGLISH (2)	I	F	S
m	3	Kg	lbm	✓		
$\dot{m}$	78	Kg/s	lbm/s	✓		
N	29	-	-	✓		
n	27	-	-	✓		
P	1	K Pa	lb/ft^2	✓	✓	✓
P_r	37	-	-		✓	✓
ΔP	39	K Pa	lb/ft^2		✓	✓
PE	14	KJ	ft.lb	✓	✓	✓
ΔPE	52	"	"		✓	✓
pe	15	KJ/Kg	ft.lb/lbm	✓	✓	✓
Δpe	53	"	"		✓	✓
PV	64	KJ	ft.lb	✓	✓	✓
ΔPV	66	"	"		✓	✓
Pv	65	KJ/Kg	ft.lb/lbm	✓	✓	✓
ΔPv	67	"	"		✓	✓

APPENDIX A. (Continued)

VARAIBLE	CODE NUMBER	UNITS OPTION		SUBSCRIPT		
		SI (1)	ENGLISH (2)	I	F	S
Q	20	KJ	ft.lb		✓	✓
q	21	KJ/Kg	ft.lb/lbm		✓	✓
$\dot{Q}$	82	KW	ft.lb/s		✓	✓
$\dot{q}$	83	KW/Kg	ft.lb/lbm.s		✓	✓
R	22	KJ/Kg°K	ft.lb/lbm°R	✓		
$\overline{R}$	23	KJ/Kg°K.mole	ft.lb/lbm°R.mole	✓		
RLPR	57	KJ/Kg°K	ft.lb/lbm°R		✓	✓
RLVR	58	"	"		✓	✓
S	10	KJ/°K.mole	ft.lb/°R.mole	✓	✓	✓
ΔS	46	"	"		✓	✓
s	11	KJ/Kg°K.mole	ft.lb/lbm°R.mole	✓	✓	✓
Δs	47	"	"		✓	✓
T	2	°K	°R	✓	✓	✓
ΔT	38	"	"		✓	✓
T_r	36	-	-		✓	✓

VARIABLE	CODE NUMBER	UNITS OPTION		SUBSCRIPT		
		SI (1)	ENGLISH (2)	I	F	S
TDS	100	°K	°R			✓
Δt	77	s	s		✓	
U	12	KJ	ft.lb	✓	✓	✓
ΔU	44	"	"		✓	✓
u	13	KJ/Kg	ft.lb/lbm	✓	✓	✓
Δu	45	"	"		✓	✓
V	4	m^3	ft^3	✓	✓	✓
ΔV	40	"	"		✓	✓
$\dot{V}$	79	m^3/s	ft^3/s	✓	✓	
V_r	35	-	-		✓	✓
$\vec{V}$	30	m/s	ft/s	✓	✓	✓
$\vec{V}_r$	96	-	-		✓	✓
v	5	m^3/Kg	ft^3/lb	✓	✓	✓
Δv	41	"	"		✓	✓
$\bar{v}$	6	$m^3/Kg.mole$	$ft^3/lb.mole$	✓	✓	✓

APPENDIX A. (Continued)

VARIABLE	CODE NUMBER	UNITS OPTION		SUBSCRIPT		
		SI (1)	ENGLISH (2)	I	F	S
W	33	KJ	ft.lb		✓	✓
W_a	71	"	"		✓	✓
$\dot{W}$	84	KW	ft.lb/s		✓	✓
$\dot{W}_a$	91	"	"		✓	✓
w	34	KJ/Kg	ft.lb/lbm		✓	✓
w_a	75	"	"		✓	✓
$\dot{w}$	85	KW/Kg	ft.lb/lbm.s		✓	✓
$\dot{w}_a$	95	"	"		✓	✓
Z	31	m	ft	✓	✓	✓
η	99	-	-	✓		
ρ	7	Kg/m^3	lb/ft^3	✓	✓	✓

APPENDIX B. General Equations and their Code Numbers

Equation Number	Equation Description
1, 2, 3	$\overline{R} = M.R$
4, 5, 6, [7, 8, 9]	$V = v.m$
10, 11, [12, 13]	$v = 1.0/\rho$
14, 15, 16	$V_r = V_F/V_I$
17, 18, 19	$V_r = v_F/v_I$
20, 21, 22	$\Delta V = V_F - V_I$
23, 24, 25	$\Delta v = v_F - v_I$
26, 27, 28	$\Delta V = \Delta v.m$
29, 30, 31	$m = M.N$
32, 33, 34, [35, 36, 37]	$v = M.\overline{v}$
38, 39, 40, 44, [41, 42, 43, 45]	$v = (T/P).R$
46, 47, 48	$V_r = T_r/P_r$
49, [50]	$m_F = m_I$
51, 52, 53	$\Delta P = P_F - P_I$
54, 55, 56	$P_r = P_F/P_I$
57, 58, 59	$\Delta T = T_F - T_I$
60, 61, 62	$T_r = T_F/T_I$

Equation Number	Equation Description
63, 64, 65	$\Delta H = H_F - H_I$
66, 67, 68	$\Delta h = h_F - h_I$
69, 70, 71, [72, 73, 74]	$H = h.m$
75, 76, 77	$\Delta H = \Delta h.m$
78, 79, 80	$\Delta U = U_F - U_I$
81, 82, 83	$\Delta u = u_F - u_I$
84, 85, 86, [87, 88, 89]	$U = u.m$
90, 91, 92	$\Delta S = S_F - S_I$
93, 94, 95	$\Delta s = s_F - s_I$
99, 100, 101, [102, 103, 104]	$S = s.m$
105, 106, 107	$\Delta S = \Delta s.m$
108, 109, 110	$w = W/m$
111, 112, 113	$q = Q/m$
114, 115, 116	$e_F = E_F/m$
117, 118	$E = U$ closed system

APPENDIX B. (Continued)

Equation Number	Equation Description
119	$\Delta E = \Delta U$ closed system
120, 121	$e = u$ closed system
122	$\Delta e = \Delta u$ closed system
149, 150, 151	$\Delta PE = PE_F - PE_I$
152, 153, 154	$\Delta KE = KE_F - KE_I$
159, 160, 161	$\Delta pe = pe_F - pe_I$
162, 163, 164	$\Delta ke = ke_F - ke_I$
169	$LPR = \ell n\ P_r$
170	$LTR = \ell n\ T_r$
171	$LVR = \ell n\ V_r$
178	$RLPR = R.LPR$
179	$RLVR = R.LVR$
180	$CVLTR = c_v.LTR$
181	$CPLTR = c_p.LTR$
182	$CPLVR = c_p.LVR$
183	$CVLPR = c_v.LPR$

APPENDIX B. (Continued)

Equation Number	Equation Description
184	$CVLVR = c_v.LVR$
199, 200, 201	$e_I = E_I/m$
202, 203, 204	$\Delta E = E_F - E_I$
205, 206, 207	$\Delta e = e_F - e_I$
210, 211, 212	$\Delta E = \Delta e.m$
213, 214, 215	$\Delta PE = \Delta pe.m$
216, 217, 218	$\Delta KE = \Delta ke.m$
219, 220, 221, [222, 223, 224]	$KE = ke.m$
225, 226, 227, [228, 229, 230]	$PE = pe.m$
231, 232, 233, 234, [235, 236, 237, 238]	$E = H + KE + PE$ open system
239, 240, 241, 242	$\Delta E = \Delta H + \Delta KE + \Delta PE$ open system
243, 244, 245, 246, [247, 248, 249, 250]	$e = h + ke + pe$ open system
251, 252, 253, 254	$\Delta e = \Delta h + \Delta ke + \Delta pe$ open system
255, 256, 257	$Q = W + \Delta E$

Equation Number	Equation Description
258, 259, 260	$q = w + \Delta e$
261, 263, 265, [262, 264, 266]	$KE = \vec{V}^2.m/2g_c$
267, 269, [268, 270]	$ke = \vec{V}^2/2g_c$
271, 273,[272, 274]	$PE = Z.m.g/g_c$
275, 277, [276, 278]	$pe = Z.g/g_c$
281, 282, 283	$K = c_p/c_v$
284, 285, 286	$R = c_p - c_v$
287, 288, 289	$c_v = R/(K - 1.0)$
290, 291, 292	$c_p = K.R/(K - 1.0)$
293, 294, 295, [296, 297, 298]	$PV = P.V$
299, 300, 301, [302, 303, 304]	$Pv = P.v$
305, 306, 307	$T_r = Pv_F/Pv_I$
308, 309, 310	$T_r = PV_F/PV_I$

Equation Number	Equation Description
311, 312, 313, [314, 315, 316]	$Pv = T.R$
317, 318, 319, [320, 321, 322]	$PV = Pv.m$
323, 324, 325	$\Delta PV = PV_F - PV_I$
326, 327, 328	$\Delta Pv = Pv_F - Pv_I$
333, 334, 335	$\Delta T = \Delta PV/m.R$
339, 340	$\Delta u = \Delta T.c_v$
341, 342	$\Delta h = \Delta T.c_p$
343, 344, 345	$\Delta u = \Delta h/K$
346	$K = \Delta H/\Delta U$
347, 349, 351, [348, 350, 352]	$h = u + Pv$
353, 355, 357, [354, 356, 358]	$H = U + PV$
359, 360, 361	$\Delta h = \Delta u + \Delta Pv$
362, 363, 364	$\Delta H = \Delta U + \Delta PV$
365, 366, 367	$W = W_f + W_a$

Equation Number	Equation Description
368, 369, 370	$w = w_f + w_a$
377, 378, 379	$W_a = Q - \Delta H$ closed system
380, 381, 382	$w_a = q - \Delta h$ closed system
385, 386, 387	$w_a = W_a/m$
391, 392, 393	$w_f = W_f/m$
405, 413, 407, [406, 414, 408]	$h = c_p.T$
409, 415, 411 , [410, 416, 412]	$u = c_v.T$
417, 418	$\Delta U = \Delta H/K$
419, 420, 421, 422, 423	$Q = W_a + \Delta U + \Delta PE + \Delta KE$ open system
424, 425, 426, 427, 428	$q = w_a + \Delta u + \Delta pe + \Delta ke$ open system
429, 432, 433	Δs = CVLTR + RLVR
430, 434, 435	Δs = CPLTR - RLPR
431, 436, 437	Δs = CPLVR + CVLPR
438	LTR = CVLTR/c_p

Equation Number	Equation Description
439	LVR = RLVR/R
440	LTR = CPLTR/c_p
441	LPR = RLPR/R
442	LVR = CPLVR/c_p
443	LPR = CVLPR/c_v
444	P_r = exp(LPR)
445	T_r = exp(LTR)
446	V_r = exp(LVR)
447, 449, 451, [448, 450, 452]	$\dot{V} = A/\vec{V}$
453, 456, 458, [454, 457, 459]	$\dot{m} = \rho.\dot{V}$
460, 461, 462	$\vec{V}_r = \vec{V}_F/\vec{V}_I$
463, 464, 465	$A_r = A_F/A_I$
470, [471]	$\dot{m}_F = \dot{m}_I$
472, 473, 474	$A_r = V_r/\vec{V}_r$

Equation Number	Equation Description
475, 476, 477	$\dot{m} = m/\Delta t$
478, [479]	$\Delta t_F = \Delta t_I$
480, 481, 482,[483, 484, 485]	$\dot{V} = V/\Delta t$
[486, 487, 488]	$\dot{E} = E/\Delta t$
[489, 490, 491]	$\dot{e} = e/\Delta t$
492, 493, 494	$\dot{Q} = Q/\Delta t$
495, 496, 497	$\dot{q} = q/\Delta t$
498, 499, 500	$\dot{W} = W/\Delta t$
501, 502, 503	$\dot{w} = w/\Delta t$
504, 455, 505	$\Delta\dot{E} = \Delta E/\Delta t$
506, 507, 508	$\dot{E} = E/\Delta t$
509, 510, 511	$\dot{e} = e/\Delta t$
512, 513, 514	$\Delta\dot{e} = \Delta e/\Delta t$
521, 522, 523	$\dot{W}_f = W_f/\Delta t$

Equation Number	Equation Description
524, 525, 526	$\dot{W}_a = W_a/\Delta t$
533, 534, 535	$\dot{w}_f = w_f/\Delta t$
536, 537, 538	$\dot{w}_a = w_a/\Delta t$
565, 566, 567	$\Delta\dot{E} = \dot{E}_F - \dot{E}_I$
568, 569, 570	$\Delta\dot{e} = \dot{e}_F - \dot{e}_I$
571, 572, 573	$\dot{Q} = \Delta\dot{E} + \dot{W}$
574, 575, 576	$\dot{q} = \Delta\dot{e} + \dot{w}$
577, 578, 579	$\dot{W} = \dot{W}_f + \dot{W}_a$
580, 581, 582	$\dot{w} = \dot{w}_f + \dot{w}_a$
589, 590, 591, [592, 593, 594]	$\dot{E} = e.\dot{m}$
595, 596, 597	$\dot{Q} = q.\dot{m}$
598, 599, 600	$\dot{W} = w.\dot{m}$
601, 602, 603	$\Delta\dot{E} = \Delta e.\dot{m}$
610, 611, 612	$\dot{W}_f = W_f.\dot{m}$
613, 614, 615	$\dot{W}_a = W_a.\dot{m}$

APPENDIX C. Isobaric Process Equations and Their Code Numbers

Equation Number	Equation Description
1001	$n = 0.0$
1002	$\Delta P = 0.0$
1003	$LPR = 0.0$
1004	$CVLPR = 0.0$
1005	$c_p = \Delta h/\Delta T$
1006, 1007, 1008	$\Delta PV = P.\Delta V$
1009, 1010, 1011	$\Delta Pv = P.\Delta v$
1012, 1013, 1014	$\Delta v = R.\Delta T/P$
1015, 1016	$W_f = \Delta PV$ closed system
1017, 1018	$w_f = \Delta Pv$ closed system
1019, 1020	$w_f = R.\Delta T$ closed system
1021	$P_r = 1.0$

APPENDIX D. Isothermal Process Equations and Their Code Numbers

Equation Number	Equation Description
1052	$n = 1.0$
1053	$\Delta T = 0.0$
1054	CVLTR = 0.0
1055	CPLTR = 0.0
1056	$T_r = 1.0$
1057	$\Delta U = 0.0$
1058	$\Delta H = 0.0$
1059	$\Delta u = 0.0$
1060	$\Delta h = 0.0$
1061, 1062, 1063	$W_f = -PV_1 . \ell n\ P_r$ closed system
1064, 1065, 1066	$w_f = -Pv_1 . \ell n\ P_r$ closed system
1067, 1068, 1069	$\Delta S = W_f/T$ closed system
1070, 1071, 1072	$\Delta s = w_f/T$ closed system

APPENDIX E. Isometric Process Equations and Their Code Numbers

Equation Number	Equation Description
1102	$n = \infty$
1103	$V_r = 1.0$
1104	LVR = 0.0
1105	CPLVR = 0.0
1106	CVLVR = 0.0
1107	$W_f = 0.0$ closed system
1108	$w_f = 0.0$ closed system
1109	$\dot{W}_f = 0.0$ closed system
1110	$\dot{w}_f = 0.0$ closed system
1111	$\Delta v = 0.0$
1112	$\Delta V = 0.0$
1116, 1117, 1118, 1119	$q = \Delta h - (\Delta P.v_F) + w_a$ open system
1123, 1124, 1125, 1126	$Q = \Delta H - (\Delta P.V_F) + W_a$ open system

APPENDIX F. Isentropic Process Equations and Their Code Numbers

Equation Number	Equation Description
1151, 1152	$n = K$
1153	$\Delta S = 0.0$
1154	$\Delta s = 0.0$
1155	$Q = 0.0$
1156	$q = 0.0$
1157	$\dot{Q} = 0.0$
1158	$\dot{q} = 0.0$
1159	$P_r = (1.0/V_r)^n$
1160	$P_r = (T_r)^{\frac{n}{n-1.0}}$
1161	$T_r = (P_r)^{\frac{n-1.0}{n}}$
1162	$T_r = (1.0/V_r)^{n-1.0}$
1163	$V_r = (1.0/P_r)^{\frac{1.0}{n}}$
1164	$V_r = (1.0/T_r)^{\frac{1.0}{n-1.0}}$
1165, 1166	$W_f = \Delta PV/(1.0 - n)$ closed system

APPENDIX G. Polytropic Process Equations and Their Code Numbers

Equation Number	Equation Description
1201	$P_r = (1.0/V_r)^n$
1202	$P_r = (T_r)^{\frac{n}{n-1.0}}$
1203	$T_r = (P_r)^{\frac{n-1.0}{n}}$
1204	$T_r = (1.0/V_r)^{n-1.0}$
1205	$V_r = (1.0/P_r)^{\frac{1.0}{n}}$
1206	$V_r = (1.0/T_r)^{\frac{1.0}{n-1.0}}$
1207, 1208	$W_f = \Delta PV/(1.0-n)$ closed system
1209, 1210	$w_f = \Delta Pv/(1.0-n)$ closed system
1211, 1212	$Q = W_f.(K-n)/(K-1.0)$ closed system
1213, 1214	$q = w_f.(K-n)/(K-1.0)$ closed system
1215, 1216	$\dot{Q} = \dot{W}_f.(K-n)/(K-1.0)$ closed system
1217, 1218	$\dot{q} = \dot{w}_f.(K-n)/K-1.0)$ closed system

APPENDIX G. (Continued)

Equation Number	Equation Description
1219	Δs = CVLVR.(K-n)
1220	Δs = CVLTR.(K-n)/(n-1.0)
1221	Δs = CPLPR.(K-n)/n
1222	CVLVR = Δs/(K-n)
1223	CVLTR = Δs.(n-1.0)/(K-n)
1224	CVLPR = Δs.n/(K-n)

APPENDIX H. Equations for Thermodynamic Devices

Equation Number	Equation Description	
1247, 1248, 1249	$TSD = T_F - T_S$	general
1250	$P_S = P_F$	general
1251, 1252, 1253	$\eta = W_F/W_S$	turbine
1254, 1255, 1256	$\eta = w_F/w_S$	turbine
1257, 1258, 1259	$\eta = \dot{W}_F/\dot{W}_S$	turbine
1260, 1261, 1262	$\eta = \dot{w}_F/\dot{w}_S$	turbine
1263, 1264, 1265	$\eta = KE_F/KE_S$	nozzle
1266, 1267, 1268	$\eta = ke_F/ke_S$	nozzle
1269, 1270, 1271	$\eta = KE_S/KE_S$	diffuser
1272, 1273, 1274	$\eta = ke_S/ke_F$	diffuser
1275, 1276, 1277	$\eta = W_S/W_F$	compressor
1278, 1279, 1280	$\eta = w_S/w_F$	compressor
1281, 1282, 1283	$\eta = \dot{W}_S/\dot{W}_F$	compressor
1284, 1285, 1286	$\eta = \dot{w}_S/\dot{w}_F$	compressor

APPENDIX I. Nomenclature for the Flow Charts and the Program Listings

A	:	Subscript of input variable
B	:	Temporary subscript of input variable
BL	:	Large number assigned to unknown variables in the OUTPUT subroutine
C	:	Variable status tester
DIX	:	Input data matrix
F	:	Final state of a process
I	:	Initial state of a process
ICI, ICF, III, IF, JJ, KKK, KS, KT, LZ, LV1, LV2, MAB, MALL, MIG, ML1, ML2, MZ1, MZ2	:	"DØ" statements indecies
IDV	:	Temporary device code number
IF1	:	Actual final state of a process
IF5	:	Isentropic final state of a process
IPRC1	:	Actual process code number
IUNIT	:	Units option code number
J	:	Variable code number
JA	:	Temporary variable code number
JF	:	Equation counter for step procedure
LAF	:	Final state of the last process in a cycle
LK	:	Number of input data for K, C_p, C_v, R and M

APPENDIX I. (Continued)

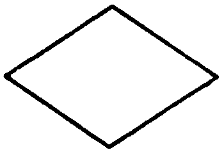
KFT	:	Temporary flow condition code number
KR	:	Computed equation number
NAR	:	Number of executed cycles
NDV	:	Device code number
NKFT	:	Flow condition code number
NPN	:	Number of executed process
NPRC	:	Process code number
NS,NT	:	Initial and/or final states of a process
PRC	:	Temporary process code number
OUT22	:	OUTPUT Subroutine
SIQ	:	Cycle heat input
SIQS	:	" " " per unit mass
SIQT	:	" " " per unit time
SIQST	:	" " " rate per unit mass
SIW	:	" work "
SIWS	:	" " " per unit mass
SIWT	:	" " " per unit time
SIWST	:	" " " rate per unit mass
SØQ	:	Cycle heat output
SØQS	:	" " " per unit mass
SØQT	:	" " " per unit time
SØQST	:	" " " rate per unit mass

APPENDIX I. (Continued)

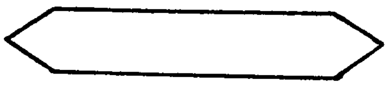
SØW	:	Cycle work output
SØWS	:	" " " per unit mass
SØWT	:	" " " per unit time
SØWST	:	" " " rate per unit mass
THEF	:	Thermal efficiency for a cycle
XX	:	Variable value
WNET	:	Cycle net work

APPENDIX J. The Symbols Used in Flow Charts

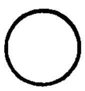
START, RETURN



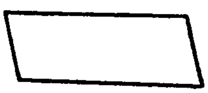
DECISION



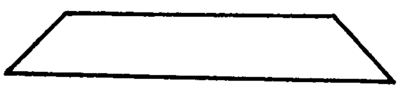
LOOPING



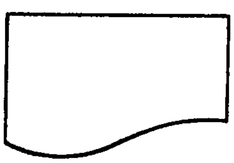
CONNECTOR



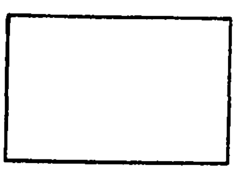
INPUT DATA



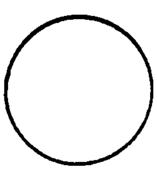
SUBROUTINE



OUTPUT RESULTS

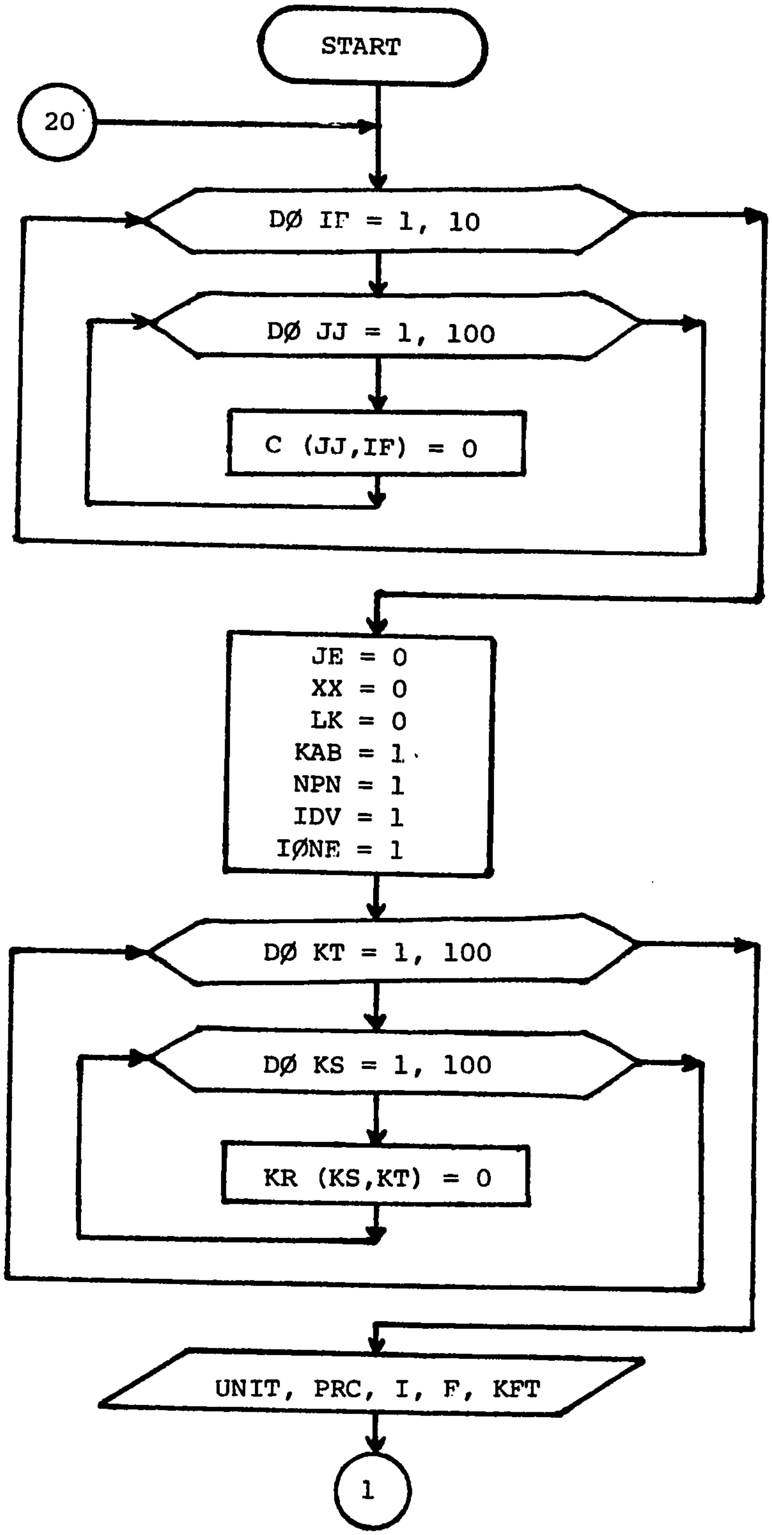


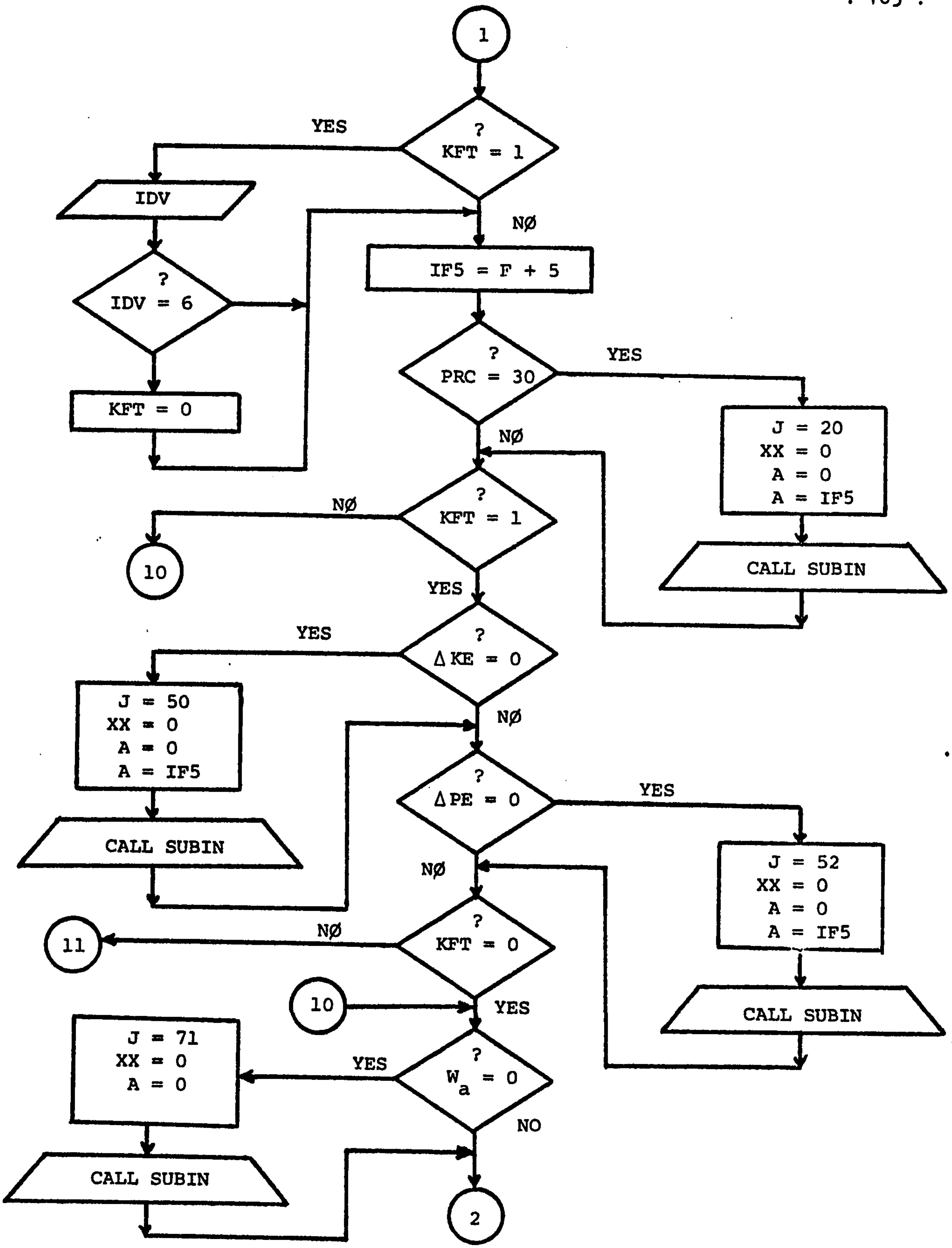
ARITHMETIC OPERATION



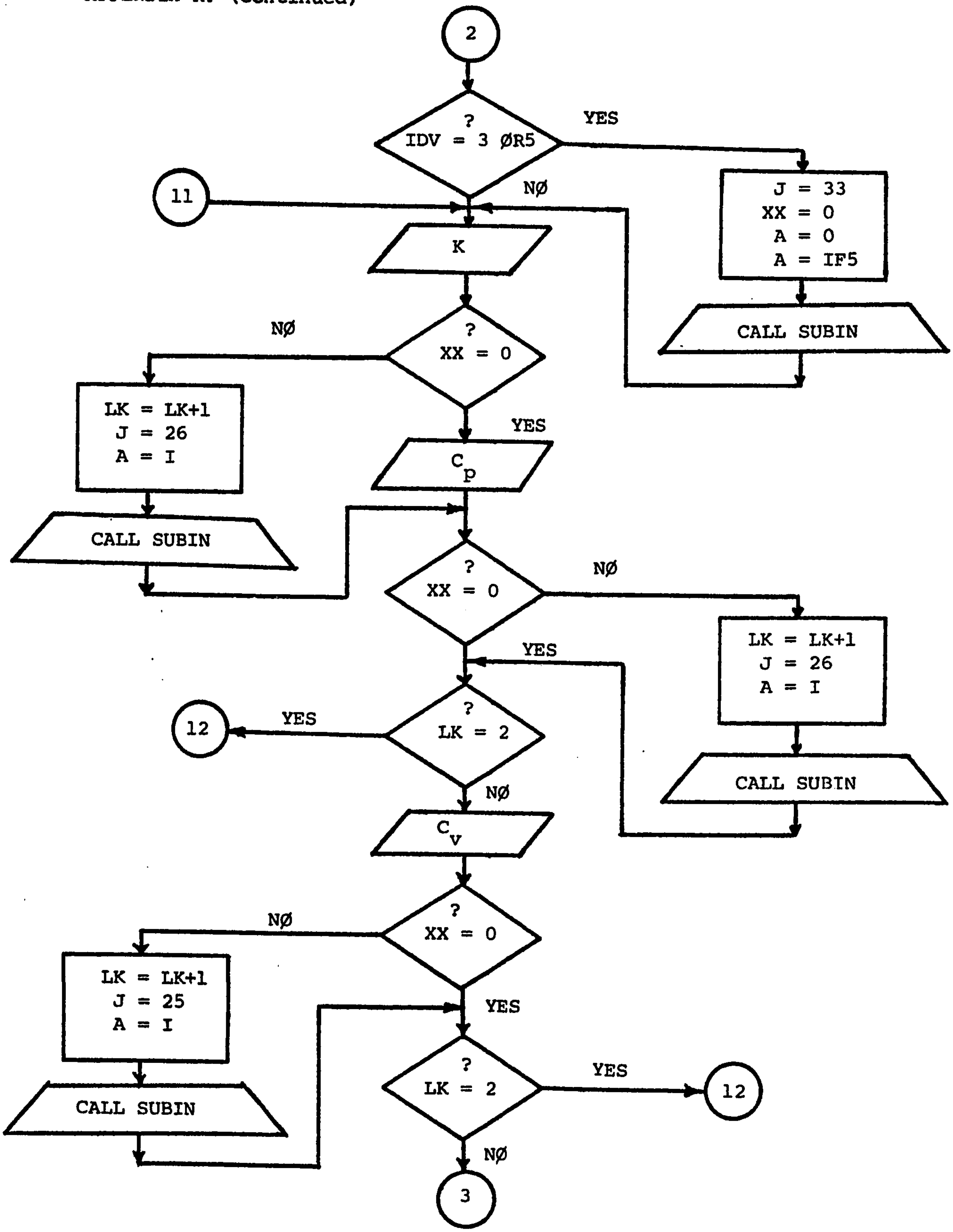
END

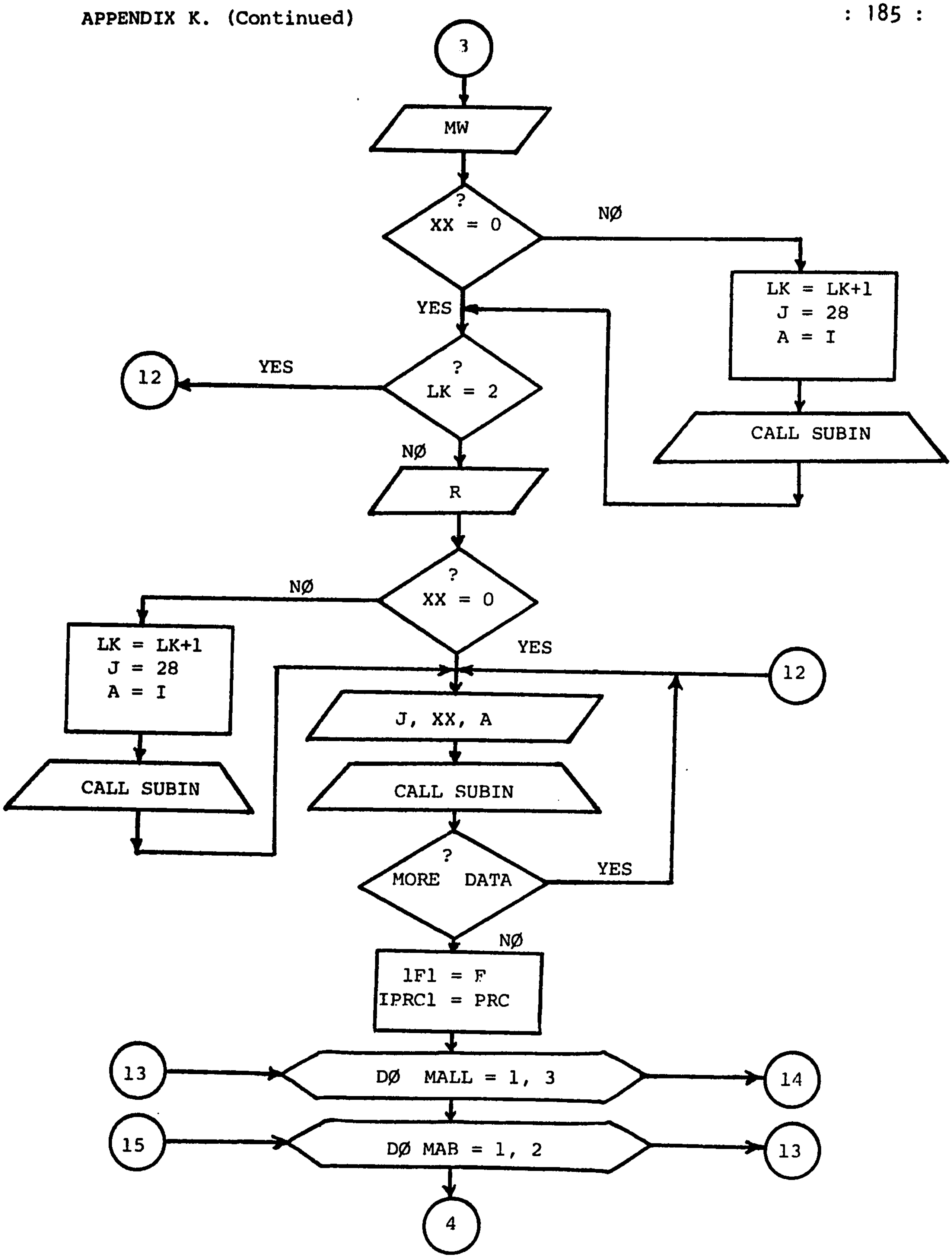
APPENDIX K. The Main Program Flow Chart



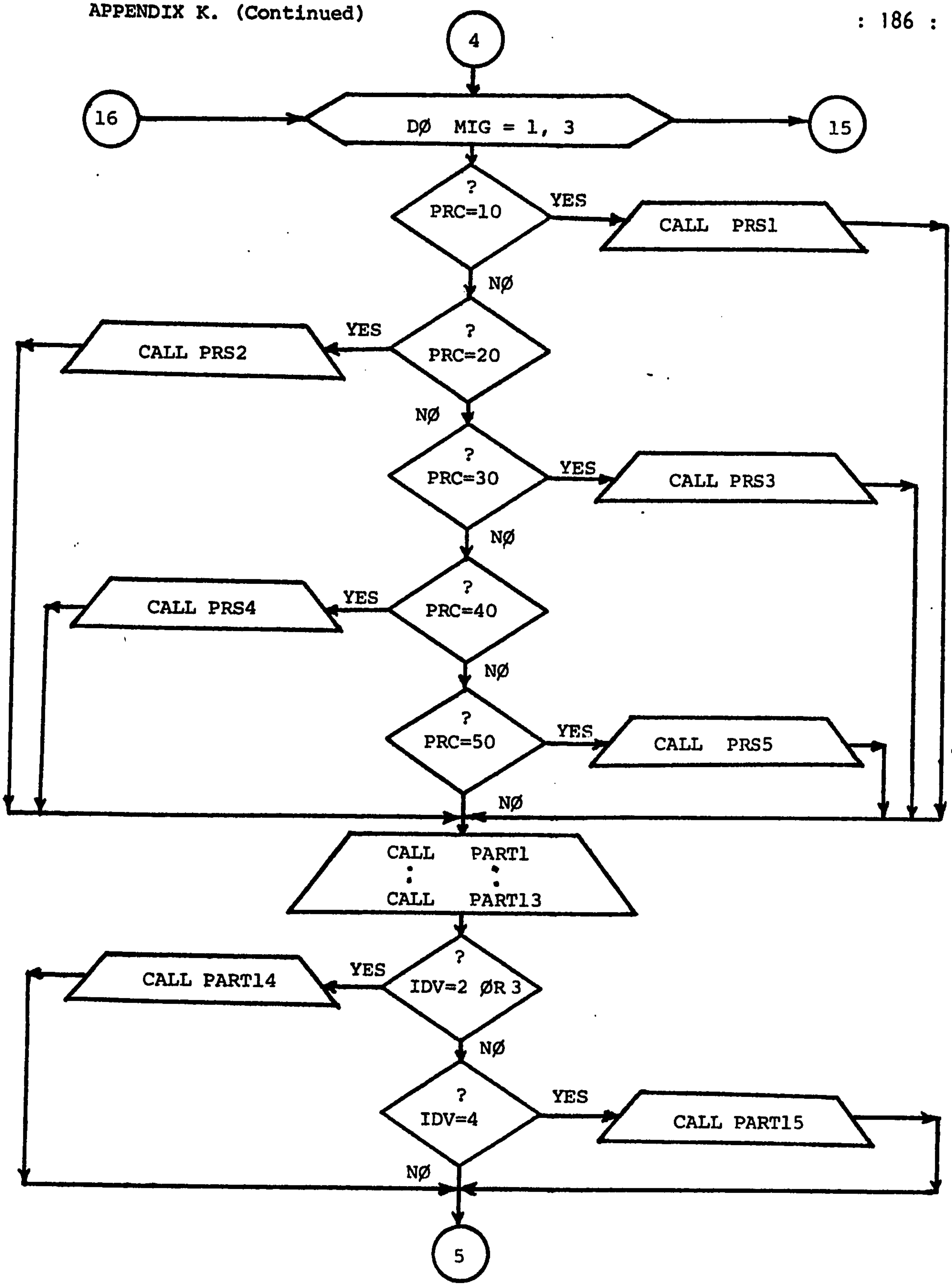

1
?
KFT = 1
YES
NØ
IDV
?
IDV = 6
KFT = 0
IF5 = F + 5
?
PRC = 30
YES
NØ
J = 20
XX = 0
A = 0
A = IF5
CALL SUBIN
?
KFT = 1
NØ
10
YES
?
ΔKE = 0
YES
NØ
J = 50
XX = 0
A = 0
A = IF5
CALL SUBIN
?
ΔPE = 0
YES
NØ
J = 52
XX = 0
A = 0
A = IF5
CALL SUBIN
?
KFT = 0
NØ
11
10
YES
?
Wa = 0
YES
NO
J = 71
XX = 0
A = 0
CALL SUBIN
2

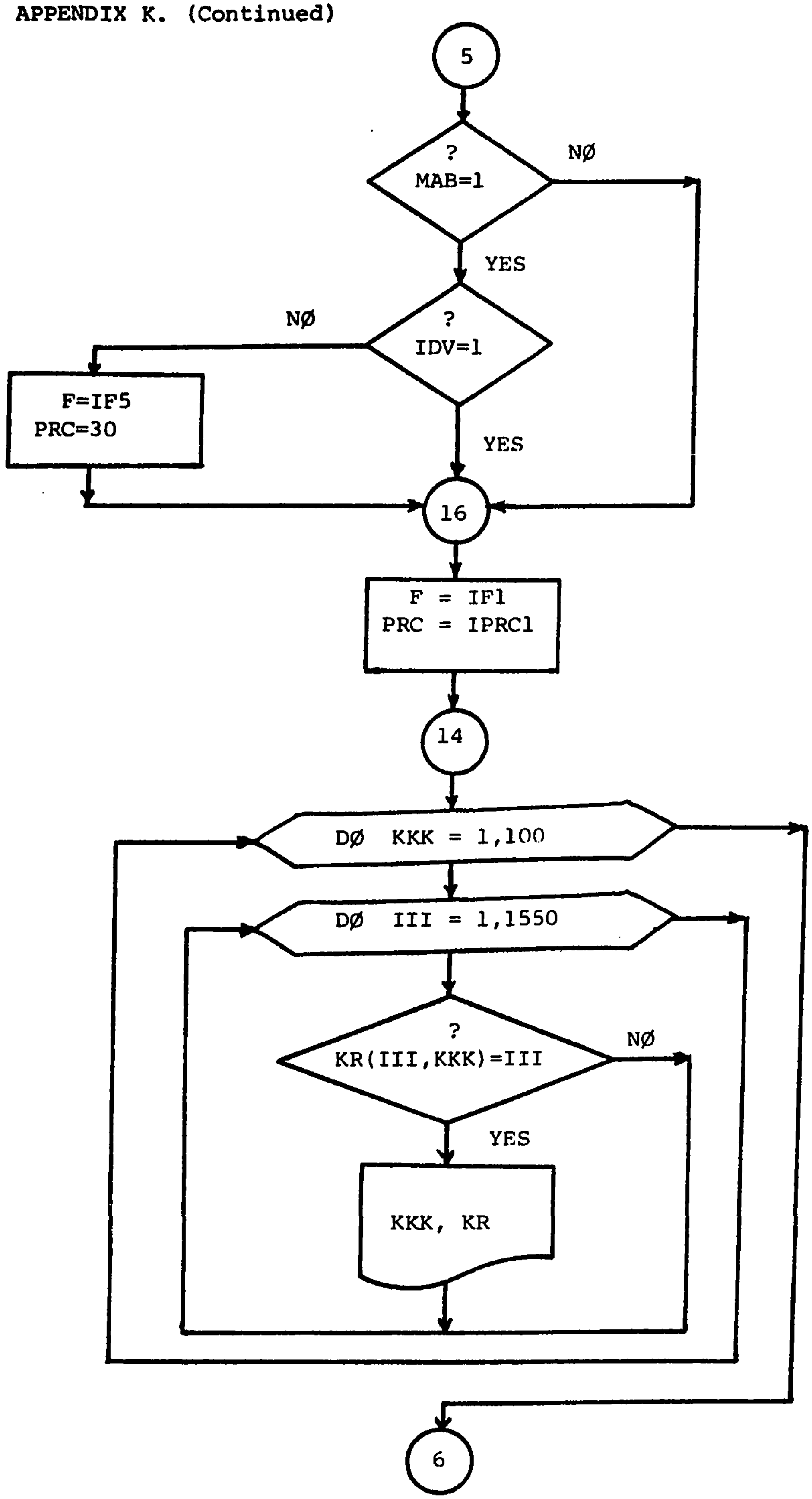
APPENDIX K. (Continued)

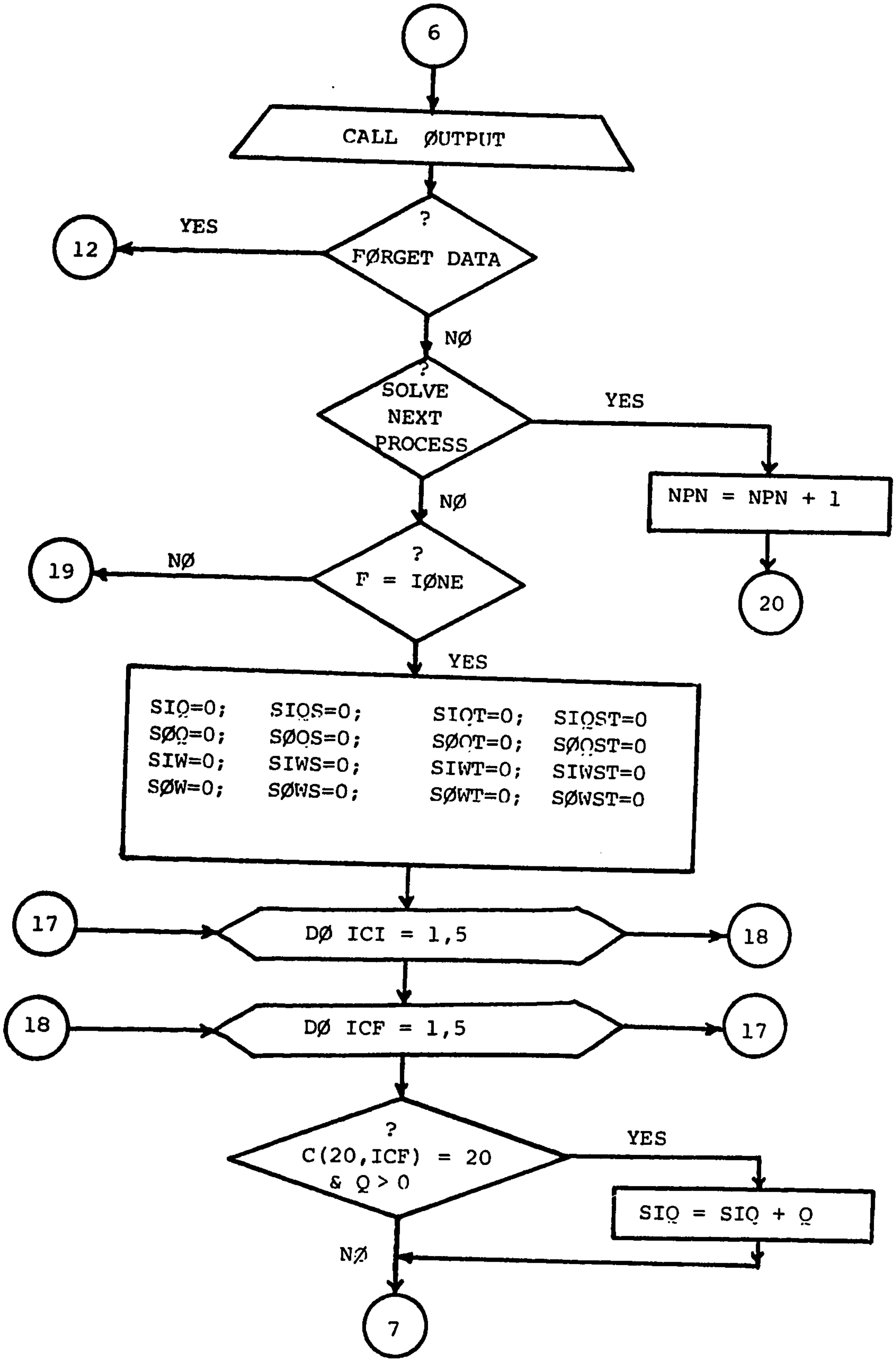


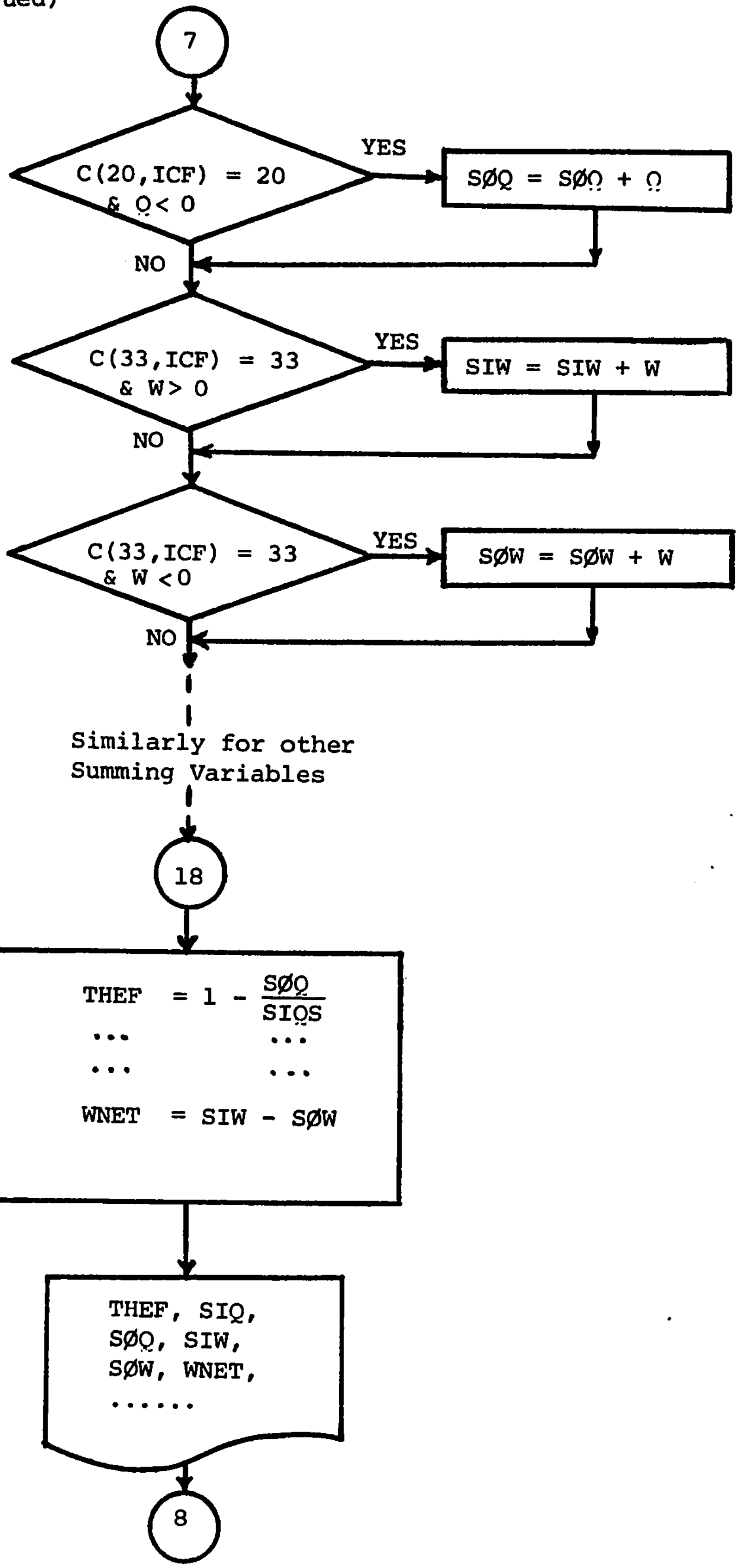

3
MW
?
XX = 0
NØ
YES
LK = LK+1
J = 28
A = I
CALL SUBIN
12
YES
?
LK = 2
NØ
R
?
XX = 0
NØ
YES
LK = LK+1
J = 28
A = I
CALL SUBIN
12
J, XX, A
CALL SUBIN
?
MORE DATA
YES
NØ
IF1 = F
IPRC1 = PRC
13
DØ MALL = 1, 3
14
15
DØ MAB = 1, 2
13
4

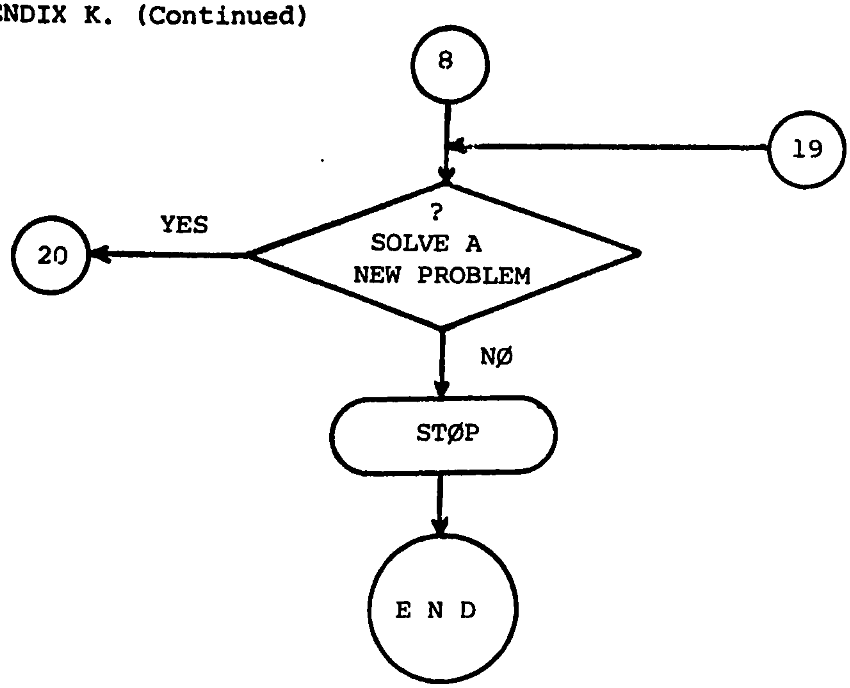
APPENDIX K. (Continued)



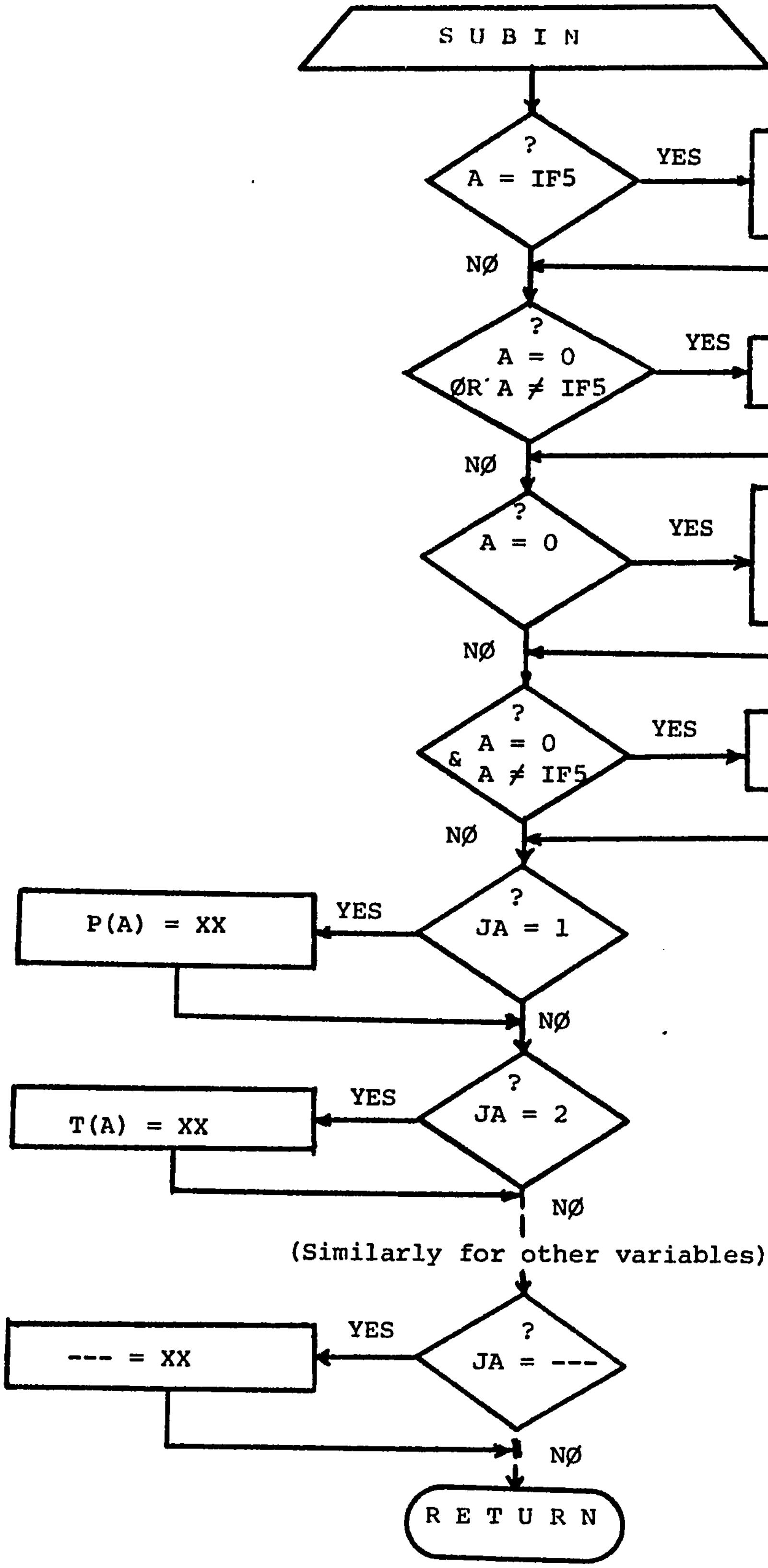

5
?
MAB=1
NØ
YES
?
IDV=1
NØ
F=IF5
PRC=30
YES
16
F = IF1
PRC = IPRC1
14
DØ KKK = 1,100
DØ III = 1,1550
?
KR(III,KKK)=III
NØ
YES
KKK, KR
6


6
CALL ØUTPUT
? FØRGET DATA
YES
12
NØ
? SOLVE NEXT PROCESS
YES
NPN = NPN + 1
20
NØ
? F = IØNE
NØ
19
YES
SIQ=0; SIQS=0; SIQT=0; SIQST=0
SØQ=0; SØQS=0; SØQT=0; SØQST=0
SIW=0; SIWS=0; SIWT=0; SIWST=0
SØW=0; SØWS=0; SØWT=0; SØWST=0
17
DØ ICI = 1,5
18
18
DØ ICF = 1,5
17
? C(20,ICF) = 20 & Q > 0
YES
SIQ = SIQ + Q
NØ
7

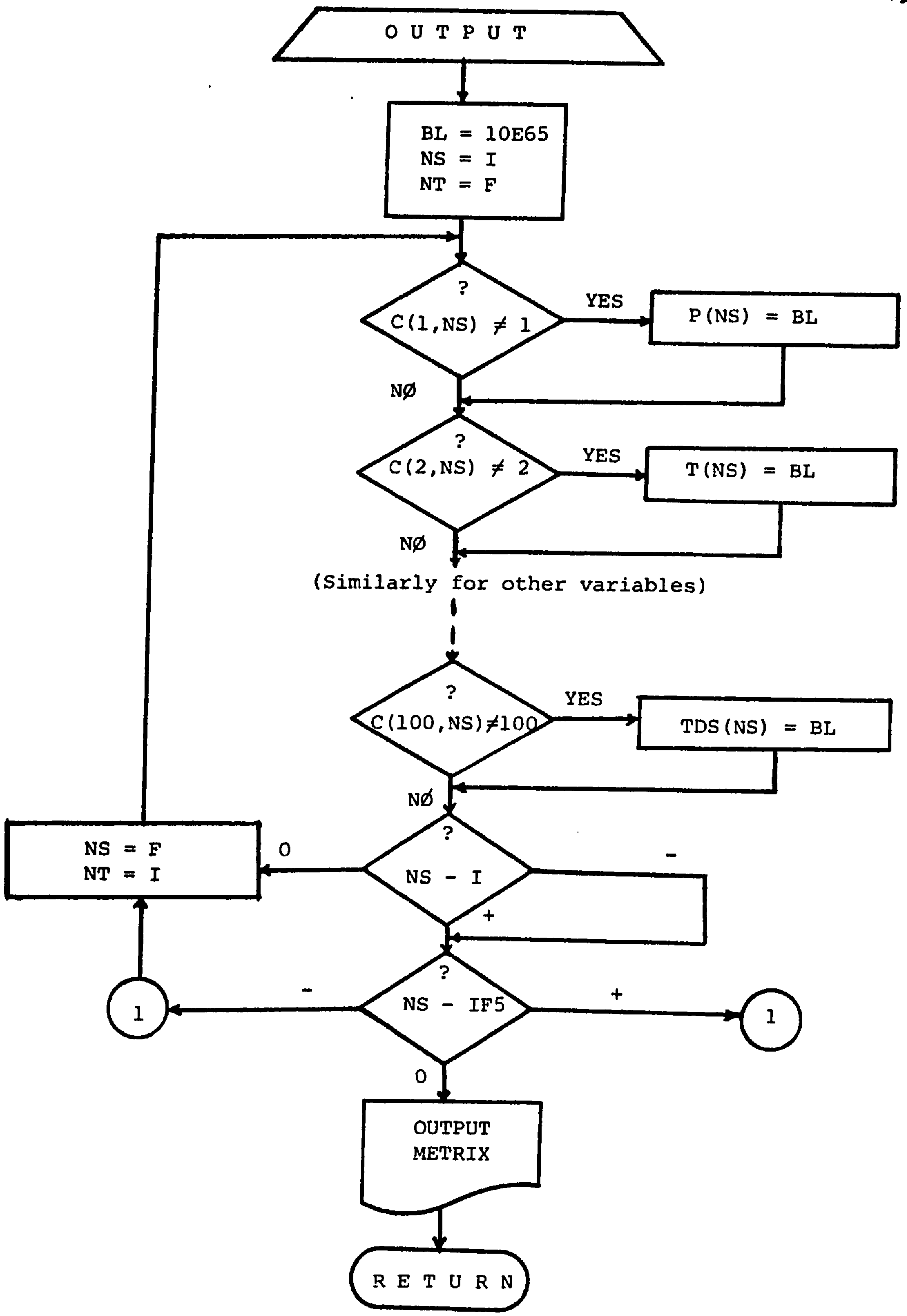

7
C(20,ICF) = 20 & Q< 0
YES
SØQ = SØQ + Q
NO
C(33,ICF) = 33 & W> 0
YES
SIW = SIW + W
NO
C(33,ICF) = 33 & W <0
YES
SØW = SØW + W
NO
Similarly for other Summing Variables
18
THEF = 1 - SØQ/SIQS
...
...
WNET = SIW - SØW
THEF, SIQ, SØQ, SIW, SØW, WNET, ...
8


8
19
YES
20
?
SOLVE A
NEW PROBLEM
NØ
STØP
E N D

APPENDIX L. The SUBIN Flow Chart



APPENDIX M. The Output Flow Chart



FORTRAN IV G1 RELEASE 2.0 MAIN DATE = 79167 12/26/11

```
      INTEGER  C(100,10),A,B,F,PRC
      REAL  M(10),KE(10),KES(10),N(10),K(10),MW(10),NM(10),KEDEL(10,10)
      REAL KESD(10,10),LPR(10,10),LTR(10,10),LVR(10,10),MFR,JTC
      DIMENSION DIX(100,10),NPRC(10),NKFT(10),NCV(10)
      COMMON C,A,B,F,PRC,M,KE,KES,N,K,MW,NM,KEDEL,KESD,LPR,LTR,LVR
      COMMON   QAS(10,10),WFS(10,10),WAS(10,10),ARV(10,10),I,JE
      COMMON   QF(10,10),QA(10,10),WF(10,10),WA(10,10),QFS(10,10)
      COMMON   ACVV(10,10),PV(10),PVS(10),PVDEL(10,10),PVSD(10,10)
      COMMON   ACVT(10,10),ACPT(10,10),ACPV(10,10),ACVP(10,10)
      COMMON   HSDEL(10,10),UDEL(10,10),USDEL(10,10),SDEL(10,10)
      COMMON   PDEL(10,10),VDEL(10,10),VSDEL(10,10),HDEL(10,10)
      COMMON   VRAT(10,10),TRAT(10,10),PRAT(10,10),TDEL(10,10)
      COMMON   PE(10),PES(10),E(10),ES(10),Q(10,10)
      COMMON   QS(10,10),R(10),RU(10),CP(10),CV(10),PEDEL(10,10)
      COMMON   VL(10),EV(10),GR(10),W(10,10),WS(10,10),AKP(10,10)
      COMMON   DN(10),H(10),HS(10),S(10),SS(10),U(10),US(10)
      COMMON   P(10),T(10),V(10),VS(10),VM(10),PESD(10,10)
      COMMON EDEL(10,10),ESDEL(10,10),SSDEL(10,10)
      COMMON KR(100,100)
      COMMON /A/ AR(10),TM(10),MFR(10),VFR(10),ET(10),EST(10),
     *QT(10,10),QST(10,10),WT(10,10),WST(10,10),ETDEL(10,10),
     *ESTD(10,10),QFT(10,10),QAT(10,10),WFT(10,10),WAT(10,10),
     *QFST(10,10),QAST(10,10),WFST(10,10),WAST(10,10),
     *VLRAT(10,10),ARRAT(10,10),JTC(10),XX,J
      COMMON /AX/ KFT
      COMMON /BX/ ILNT
      COMMON /NEW/ IFS , IDV , EFF(10) , TSC(10)
C*******************************************************************************
C********************      M A I N     P R O G R A M     ********************
C*******************************************************************************
      DATA  KYES/'YES '/,KYEES/'Y   '/,NOON/'NO  '/,NON/'N   '/
 7501 WRITE(6,8501)
      WRITE(14,8501)
 8501 FORMAT(/,5(/),80('*'),/,'     THIS IS A GENERAL PROGRAM TO AID',
     *' THE SOLUTION OF THERMODYNAMIC PROCESSES',
     */,'     AND CYCLES BASED ON IDEAL GAS RELATIONSHIPS',/,80('*'),///)
C-------------------------------------------------------------------------------
C------------------- INITIALIZING VARIABLE CODES -------------------------------
C-------------------------------------------------------------------------------
      VIL = 99999999.
      NAR = 0
      LAF = 2
 7500 DO 901 IF= 1,10
      DO 901 JJ= 1,100
      C(JJ,IF) = 0
      DIX(JJ,IF) = VIL
  901 CONTINUE
      XX  = 0.0
      NPN = 1
      IDV = 1
      IONE = 1
C-------------------------------------------------------------------------------
 7502 WRITE(6,8502)
      WRITE(14,8502)
 8502 FORMAT(/,'   PLEASE ENTER : -',
     */,2X,18('-'),
     */,'  UNITS OPTION:-  1  FOR METRIC UNITS , 2  FOR ENGLISH UNITS',
     */,'  PROCESS CODE NUMBER :- ',
     */,'              ISOBARIC    PROCESS    10 ',
     */,'              ISOTHERMAL  PROCESS    20 ',
     */,'              ISENTROPIC  PROCESS    30 ',
     */,'              ISOMETRIC   PROCESS    40 ',
     */,'              POLYTROPIC  PROCESS    50 ',
     */,'              GENERAL     PROCESS   100 ',
     */,'              E  X  I  T              0 ',
     */,'  INITIAL STATE OF THE PROCESS , ',
     */,'  FINAL STATE OF THE PROCESS : AND  ',
     */,'  FLOW CONDITION:-  1  FOR STEADY FLOW , 0  FOR NON-FLOW ',/)
C------------------- INITIALIZING STEP CODES ---------------------------
      XX = 0.0
      JE = 0
      LK = 0
      DO 9050 KT = 1,100
      DO 9050 KS = 1,200
 9050 KR(KS,KT) = 0
```

```
C-----------------------------------------------------------------------
C------------------  READING & WRITING DATA  ---------------------------
C-----------------------------------------------------------------------
      READ(5,*)  IUNT, PRC, I, F, KFT
      WRITE(14,*)  IUNT, PRC, I, F, KFT
      IF(KFT.EQ.1) WRITE(6,8571)
      IF(KFT.EQ.1) WRITE(14,8571)
 8571 FORMAT(/,'    PLEASE ENTER THE DEVICE CODE NUMBER :',
     */,42('-'),
     */,' HEAT EXCHANGER: 1  , TURBINE: 2  , NOZZLE: 3  ,',
     *'  COMPRESSOR: 4  , DIFFUSER: 5  ',
     */,'  PISTON: 6 ',
     *' , OTHERS: 7 ',/)
      IF(KFT.EQ.1) READ(5,*)  IDV
      IF(KFT.EQ.1) WRITE(14,*)  IDV
 7504 WRITE(6,8504)  IUNT, PRC, I, F, KFT
      WRITE(14,8504)  IUNT, PRC, I, F, KFT
 8504 FORMAT(//,'     YOU ENTERED THE FOLLOWING DATA :-',
     */,50('-'),
     */,'   UNITS  OPTION        =',I4,
     */,'   PROCESS CODE NUMBER =',I4,
     */,'   INITIAL STATE       =',I4,
     */,'   FINAL STATE         =',I4,
     */,'   FLOW CONDITION      =',I4 )
      IF(KFT.EQ.1) WRITE(6,8572)IDV
      IF(KFT.EQ.1) WRITE(14,8572)IDV
 8572 FORMAT('   DEVICE CODE NUMBER  =',I4)
      WRITE(6,8573)
      WRITE(14,8573)
 8573 FORMAT(50('-'),
     */,' *** IF OK , TYPE IN YES, IF NOT TYPE IN NO',/)
 7505 READ(5,8505)LETTER
      WRITE(14,8505)LETTER
 8505 FORMAT(A4)
      IF(LETTER.EQ.NON.OR.LETTER.EQ.NOON)  GOTO  7502
      JI1 = I
      JF1 = F
C---------------------------  ERROR  CHECKING  -------------------------
      IF(I.EQ.F)GO TO  7502
      IF(KFT.GT.1)GO TO  7502
      IF(IUNT.GT.2)GO TO  7502
      IF(PRC.EQ.0)GO TO  7520
C-----------------------------------------------------------------------
C------------------  FINDING ISENTROPIC FINAL POINT  -------------------
C-----------------------------------------------------------------------
      IF(IDV.EQ.6)  KFT = 0
      IF(IDV.EQ.7.AND.PRC.EQ.20)  KFT = 0
      NPRC(NPN) = PRC
      NKFT(NPN) = KFT
      NDV(NPN) = IDV
      IF5 = F + 5
      WRITE(6,9997)IF5
      WRITE(14,9997)IF5
 9997 FORMAT(/,' SUBSCRIPT OF ISENTROPIC  FINAL  STATE   = ', I5)
C-----------------------------------------------------------------------
C-----------------  CHECKING FOR  :  Q & W & KE & PE  ------------------
C-----------------------------------------------------------------------
 7564 IF(PRC.EQ.30)GO TO 7579
      WRITE(6,8564)
      WRITE(14,8564)
 8564 FORMAT(/,80('-'),/,'       IS IT AN ADIABATIC PROCESS ? ',
     */,' **  PLEASE ENTER EITHER   YES  OR  NO ' ,
     */,80('-') )
      READ(5,8505)LETTER
      WRITE(14,8505)LETTER
      IF(LETTER.EQ.NON.OR.LETTER.EQ.NOON)  GOTO   5000
 7579 J = 20
      XX = 0.0
      A = F
      DIX(J,A) = XX
      CALL SUBIN
      A = IF5
      DIX(J,A) = XX
      CALL SUBIN
 5000 IF(KFT.EQ.1)GO TO  7550
      GO TO  7554
 7550 WRITE(6,8550)
      WRITE(14,8550)
```

```
      8550 FORMAT(/,80('-'),/,'    IS THERE A KINETIC ENERGY CHANGE ? ',
     */,' **  PLEASE ENTER EITHER    YES  OR  NO ' ,
     */,80('-') )
      7551 READ(5,8505)LETTER
           WRITE(14,8505)LETTER
           IF(LETTER.EQ.KYES.OR.LETTER.EQ.KYEES)  GOTO  7552
           J = 50
           XX = 0.0
           A = F
           DIX(J,A) = XX
           CALL SUBIN
           A = IF5
           DIX(J,A) =  XX
           CALL SUBIN
      7552 WRITE(6,8552)
           WRITE(14,8552)
      8552 FORMAT(/,80('-'),/,'    IS THERE A POTENTIAL ENERGY CHANGE ? ',
     */,' **  PLEASE ENTER EITHER    YES  OR  NO ' ,
     */,80('-') )
           READ(5,8505)LETTER
           WRITE(14,8505)LETTER
           IF(LETTER.EQ.KYES.OR.LETTER.EQ.KYEES)  GOTO  7554
           J = 52
           XX = 0.0
           A = F
           DIX(J,A) = XX
           CALL SUBIN
           A = IF5
           DIX(J,A) = XX
           CALL SUBIN
      7554 IF(KFT.EQ.0)GO TO 7555
           GO TO 7565
      7555 WRITE(6,8555)
           WRITE(14,8555)
      8555 FORMAT(/,80('-'),/,'       IS THERE AN EXTERNAL WORK TERM ? ',
     */,' **  PLEASE ENTER EITHER    YES  OR  NO ' ,
     */,80('-') )
           READ(5,8505)LETTER
           WRITE(14,8505)LETTER
           IF(LETTER.EQ.KYES.OR.LETTER.EQ.KYEES)  GOTO  7565
           J = 71
           XX = 0.0
           A = F
           DIX(J,A) = XX
           CALL SUBIN
      7565 IF(IDV.EQ.3.OR.IDV.EQ.5)  GOTO  7578
           GO TO 7557
      7578 J = 33
           XX = 0.0
           A = F
           DIX(J,A) = XX
           CALL SUBIN
           A = IF5
           DIX(J,A) = XX
           CALL SUBIN
      7577 CONTINUE
C------------------------------------------------------------------------
C--------------------- STORED  VALUES  ----------------------------------
C------------------------------------------------------------------------
      7557 WRITE(6,8557)
           WRITE(14,8557)
      8557 FORMAT(/,80('#'),
     */,' THE VALUES OF THE FOLLOWING CONSTANTS',
     *' ARE STORED FOR YOU :- ',
     */,'  RU = 8.3150    SI UNIT','          RU = 1545   ENGLISH UNIT',
     */,'  G  = 9.80      SI UNIT','          G  = 32.2   ENGLISH UNIT',
     */,'  GC = 1.0       SI UNIT','          GC = 32.2   ENGLISH UNIT',
     */,' IF YOU LIKE TO CHANGE',
     *' THE VALUE OF EACH CONSTANT REPLACE IT BY A PROPER VALUE',
     */,80('#'))
C------------------------------------------------------------------------
C-------------  ENTERING DATA FOR : K & CP & CV & R & MW  --------------
C------------------------------------------------------------------------
      7566 WRITE(6,8566)
           WRITE(14,8566)
      8566 FORMAT(/,'       PLEASE ENTER THE VALUE OF (26):K , IF IT IS ',
     *' UNKNOWN ENTER  0 ',/)
           READ(5,*)XX
           WRITE(14,*)XX
```

```
      IF(XX.EQ.0.0)GO TO 7567
      LK = LK + 1
      J = 26
      A = I
      DIX(J,A) = XX
      CALL SUBIN
 7567 WRITE(6,8567)
      WRITE(14,8567)
 8567 FORMAT(/,'     PLEASE ENTER THE VALUE OF (24):CP , IF IT IS ',
     *' UNKNOWN ENTER  0 ',/)
      READ(5,*)XX
      WRITE(14,*)XX
      IF(XX.EQ.0.0)GO TO 7568
      LK = LK + 1
      J = 24
      A = I
      DIX(J,A) = XX
      CALL SUBIN
 7568 IF(LK.EQ.2)GO TO 7506
      WRITE(6,8568)
      WRITE(14,8568)
 8568 FORMAT(/,'     PLEASE ENTER THE VALUE OF (25):CV , IF IT IS ',
     *' UNKNOWN ENTER  0 ',/)
      READ(5,*)XX
      WRITE(14,*)XX
      IF(XX.EQ.0.0)GO TO 7569
      LK = LK + 1
      J = 25
      A = I
      DIX(J,A) = XX
      CALL SUBIN
 7569 IF(LK.EQ.2)GO TO 7506
      WRITE(6,8569)
      WRITE(14,8569)
 8569 FORMAT(/,'     PLEASE ENTER THE VALUE OF (28):MW , IF IT IS ',
     *' UNKNOWN ENTER  0 ',/)
      READ(5,*)XX
      WRITE(14,*)XX
      IF(XX.EQ.0.0)GO TO 7570
      LK = LK + 1
      J = 28
      A = I
      DIX(J,A) = XX
      CALL SUBIN
 7570 IF(LK.EQ.2)GO TO 7506
      WRITE(6,8570)
      WRITE(14,8570)
 8570 FORMAT(/,'     PLEASE ENTER THE VALUE OF (22):R  , IF IT IS ',
     *' UNKNOWN ENTER  0 ',/)
      READ(5,*)XX
      WRITE(14,*)XX
      IF(XX.EQ.0.0)GO TO 7506
      LK = LK + 1
      J = 22
      A = I
      DIX(J,A) = XX
      CALL SUBIN
C-------------------------------------------------------------------------
C------------------- READING & WRITING THE REST OF DATA -------------------
C-------------------------------------------------------------------------
      JI1 = I
      JF1 = F
C------------------- CHECKING FOR CYCLE COMPLTATION -----------------------
 7506 IF(NAR.EQ.0) GO TO  7753
      WRITE(6,8751)
      WRITE(14,8751)
 8751 FORMAT(/,'     PLEASE ENTER THE INITAIL AND FINAL STATES OF THE',
     */,'     PROCESS TO WHICH THE NEW VALUES ARE ASSOCIATED WITH',/)
      READ(5,*)I,F
      WRITE(14,*)I,F
      IF5 = F + 5
C-------------------------------------------------------------------------
 7753 WRITE(6,8506)
      WRITE(14,8506)
 8506 FORMAT(//,40('*-'),
     */,'     NOW , PLEASE ENTER THE REST OF THE DATA OR THE ',
     *'NEW VALUES ' ,
     */,'     IN THE FOLLOWING ORDER  :- ' ,
     */,'     VARIABLE CODE NUMBER  ,  VALUE  ,  AND SUBSCRIPT' ,
     */,'     IF THERE ARE NO DATA AVAILABLE , PLEASE ENETER : 0  0  0',
     */,40('-*'),//)
      READ(5,*)J,XX,A
      WRITE(14,*)J,XX,A
 7508 WRITE(6,8508)J,XX,A
```

```
              WRITE(14,8508)J,XX,A
        8508  FORMAT(1X,//,'     THE DATA YOU ENTERED ARE :-',
             */,50('-'),
             */,'    VARIABLE CODE NUMBER =',I6,
             */,'    VALUE                =',F12.5,
             */,'    SUBSCRIPT            =',I6,
             */,50('-'),
             */,' ***IF OK , TYPE IN YES, IF NOT TYPE IN NO',/)
        7509  READ(5,8505)LETTER
              WRITE(14,8505)LETTER
              IF(LETTER.EQ.NON.OR.LETTER.EQ.NCON)  GOTO  7506
      C-------------------  ERROR CHECKING  -----------------------------------
              IF(J.EQ.0.AND.NAR.EQ.0)  GOTO  900
              IF(J.EQ.0.AND.NAR.EQ.1)  GOTO 7767
              IF(J.GT.101)  GOTO  7506
              IF(A.EQ.0) A = F
              DIX(J,A) = XX
              CALL SUBIN
              I = JI1
              F = JF1
              IF5 = F + 5
        7510  WRITE(6,8510)
              WRITE(14,8510)
        8510  FORMAT(//,'       DO YOU WANT TO ADD OR CHANGE DATA ?',
             */,' ***  TYPE IN EITHER  YES  OR  NO',/)
              READ(5,8505)LETTER
              WRITE(14,8505)LETTER
              IF(LETTER.EQ.KYES.OR.LETTER.EQ.KYEES)  GOTO  7506
      C------------------------------------------------------------------------
      C--------------------  CALLING COMPUTATION SUBROUTINES  ----------------
      C------------------------------------------------------------------------
        7767  IF(NAR.EQ.1) GOTO  7766
              GO  TO  900
      C-------------------   INITIALIZING STEP COUNTER   -------------------
      C-------------------  & COMPUTING CYCLIC PROCESSES  -------------------
        7766  DO 969 LZ = 1 , LAF
              DO 355 MZ1 = 1 , 100
              DO 355 MZ2 = 1 , 200
              KP(MZ2,MZ1) = 0
        355   CONTINUE
              JE = 0
              I = LZ
              F = I + 1
              IF(F.GT.LAF) F = IONE
              IF(F.LT.5)IF5 = F + 5
              PRC = NPRC(LZ)
              KFT = NKFT(LZ)
              IDV = NDV(LZ)
      C------------------------------------------------------------------------
        900   IF1 = F
              IPRC1 = PRC
              DO 957 MALL = 1,3
              DO 955 MAB  = 1,2
        903   DO 904 MIG  = 1,3
              IF(PRC.EQ.10)CALL PRS1
              IF(PRC.EQ.20)CALL PRS2
              IF(PRC.EQ.30)CALL PRS3
              IF(PRC.EQ.40)CALL PRS4
              IF(PRC.EQ.50)CALL PRS5
              CALL PART1
              CALL PART2
              CALL PART3
              CALL PART4
              CALL PART5
              CALL PART6
              CALL PART7
              CALL PART8
              CALL PART9
              CALL PART10
              CALL PART11
              CALL PART12
              CALL PART13
              IF(IDV.EQ.2.OR.IDV.EQ.3.OR.IDV.EQ.5.OR.IDV.EQ.4)CALL PART14
              IF(IDV.EQ.4)CALL PART15
              IF(MAB.EQ.1) GO TO 904
              IF(IDV.EQ.2.OR.IDV.EQ.3.OR.IDV.EQ.4.OR.IDV.EQ.5)F = IF5
              IF(IDV.EQ.2.OR.IDV.EQ.3.OR.IDV.EQ.4.OR.IDV.EQ.5)PRC = 30
        904   CONTINUE
        955   CONTINUE
              F = IF1
              PRC = IPRC1
        957   CONTINUE
              IF(NAR.EQ.0)GOTO   7530
```

```
      C------------------  WRITING CYCLE RESULTS  -------------------------
      7746 WRITE(6,8748) LZ , PRC , I , F
           WRITE(14,8748)LZ , PRC , I , F
      8748 FORMAT(///,25X,'*****  R E S U L T S  *****',
          *//,' PROCESS # =',I2,5X,'PROCESS CODE # =',I3,5X,
          *'INITIAL STATE =',I2,5X,'FINAL STATE =',I2,
          */,83('-'))
           CALL  OUT22
      969  CONTINUE
           NAK = 0
           LAF = 2
           GO  TO  7898
      C-------------------------------------------------------------------
      C--------------------  PRINTING PROCEDURE STEPS  --------------------
      C-------------------------------------------------------------------
      7530 WRITE(6,8530)
           WRITE(14,8530)
      8530 FORMAT(//,'      WOULD YOU LIKE TO SEE THE SOLUTION PROCEDURE ?',
          */,' ***  TYPE IN EITHER  YES  OR  NO',/)
      7531 READ(5,8505)LETTER
           WRITE(14,8505)LETTER
           IF(LETTER.EQ.NON.OR.LETTER.EQ.NCON)  GOTO  7525
           KABI = 1
           DO 9066 KKK = 1,100
           DO 9066 III = 1,1550
           IF(KR(III,KKK).EQ.III)GO TO  9070
           GO TO 9066
      9070 WRITE(6,9077)KKK,KR(III,KKK)
           WRITE(14,9077)KKK,KR(III,KKK)
           KABI = 2
      9066 CONTINUE
      9077 FORMAT(17X,'STEP NUMBER',I5,' , USE EQUATION NUMBER',I5)
      7560 IF(KABI.EQ.1)WRITE(6,8560)
           IF(KABI.EQ.1)WRITE(14,8560)
      8560 FORMAT(/,80('+'),/,'           NO CALCULATIONS PERFORMED DUE TO',
          *'  INSUFFICIENT INPUT DATA',/,80('+'))
      C-------------------------------------------------------------------
      C--------------------  PRINTING  PROCESS  RESULTS  ------------------
      C-------------------------------------------------------------------
      7525 WRITE(6,8525) NPN , PRC , I , F
           WRITE(14,8525) NPN , PRC , I , F
      8525 FORMAT(///,25X,'*****  R E S U L T S  *****',
          *//,' PROCESS # =',I2,5X,'PROCESS CODE # =',I3,5X,
          *'INITIAL STATE =',I2,5X,'FINAL STATE =',I2,
          */,83('-'))
           CALL OUT22
      C-------------------------------------------------------------------
      C---------------  CHECKING FOR SOLVING ANOTHER PROCESS  -------------
      C-------------------------------------------------------------------
      7511 WRITE(6,8511)
           WRITE(14,8511)
      8511 FORMAT(//,'      DID YOU FORGET TO ENTER OTHER DATA ?',
          */,' ***   TYPE IN EITHER  YES  OR  NO',/)
      7512 READ(5,8505)LETTER
           WRITE(14,8505)LETTER
           IF(LETTER.EQ.KYES.OR.LETTER.EQ.KYEES)  GOTO  7506
      7533 WRITE(6,8533)
           WRITE(14,8533)
      8533 FORMAT(//,'      WOULD YOU LIKE TO SEE THE RESULTS AGAIN ?',
          */,' ***  TYPE IN EITHER  YES  OR  NO',/)
           READ(5,8505)LETTER
           WRITE(14,8505)LETTER
           IF(LETTER.EQ.KYES.OR.LETTER.EQ.KYEES)  GOTO  7530
           WRITE(6,8693)
           WRITE(14,8693)
      8693 FORMAT(//,'     WOULD YOU LIKE TO SOLVE THE SAME PROCESS WITH ',
          */,'      NEW VALUES FOR SOME OF THE VARIABLES  ?',
          */,' ***  TYPE IN EITHER   YES   OR   NO',/)
           READ(5,8505)LETTER
           WRITE(14,8505)LETTER
           IF(LETTER.EQ.KYES.OR.LETTER.EQ.KYEES)  GOTO  8727
           GO  TO  7513
      C------------------  INITIALIZING V.S.T'S & STEP COUNTER  ------------
      8727 DO 8731 JH1 = 1 , 10
           DO 8731 JH2 = 1 , 100
           C(JH2,JH1)= 0
      8731 CONTINUE
           DO 8741 KO = 1 , 100
           DO 8741 KU = 1 , 200
      8741 KR(KU,KO) = 0
           JE = 0
```

APPENDIX N. (Continued)

```
      C------------------- RESTORING PROCESS INPUT DATA ---------------------C4E6C034
            DO 8699 LCP = 1 , 100                                            04E70000
            IF(DIX(LCP,I).EQ.VIL)  GOTO  8657                                C4E8C036
            J = LCP                                                          C4850000
            XX = DIX(LCP,I)                                                  C45CCOC0
            A = I                                                            C451COC0
            CALL SUBIN                                                       C452C000
      8657  IF(DIX(LCP,F).EQ.VIL)  GOTO  8658                                C453C036
            J = LCP                                                          C454CC00
            XX = DIX(LCP,F)                                                  C455COC0
            A = F                                                            C456COC0
            CALL SUBIN                                                       C457C000
      8698  IF(DIX(LCP,IF5).EQ.VIL) GOTO 8699                                C458C036
            J = LCP                                                          C459C036
            XX = DIX(LCP,IF5)                                                C5CCC036
            A = IF5                                                          05C1C036
            CALL SUBIN                                                       0502C036
      8699  CONTINUE                                                         05C30000
            GO  TO   7506                                                    C5C4C000
      C------- CHECKING FOR SOLVING A NEXT PROCESS ON A CYCLE --------------05050034
      7513  WRITE(6,8513)                                                    C5C6C0C0
            WRITE(14,8513)                                                   C5C7C000
      8513  FORMAT(//,'      WOULD YOU LIKE TO KEEP THE RESULTS AND PROCEED ', 05CFC000
           */,'         TO SOLVE THE NEXT PROCESS  ?',                       C5C9C000
           */,' ***  TYPE IN EITHER    YES   OR    NO',/)                    C51CC000
      7514  READ(5,8505)LETTER                                               C511C0C0
            WRITE(14,8505)LETTER                                             C512CC00
            IF(LETTER.EQ.NON.OR.LETTER.EQ.NOON)  GOTO  7898                  0513C000
            NPN = NPN + 1                                                    05140000
            GO TO  7502                                                      C5150000
      C---------------------------------------------------------------------0516C000
      C---------------- COMPUTING CYCLE RESULTS ----------------------------0517C034
      C---------------------------------------------------------------------0518C034
      7898  IF(NPN.GE.3.AND.F.EQ.IONE)GO TO  7899                            0519CC00
            GO TO  7523                                                      C52CC000
      7899  SIQ = 0.0                                                        0521C000
            SIQS = 0.0                                                       C522C000
            SOQ  = 0.0                                                       C523CC00
            SOQS = 0.0                                                       0524C000
            SIW = 0.0                                                        C525C000
            SIWS = 0.0                                                       C526CCC0
            SOW = 0.0                                                        0527C000
            SOWS = 0.0                                                       C528C000
            DO 949 ICI = 1 , 5                                               C529C0C0
            DO 949 ICF = 1 , 5                                               C53CC000
            IF(C(20,ICF).EQ.20.AND.Q(ICF,ICI).GT.0.                          0531C000
           *AND.Q(ICF,ICI).LT.99999999.)SIQ=SIQ+Q(ICF,ICI)                   C532C0C0
            IF(C(21,ICF).EQ.21.AND.QS(ICF,ICI).GT.0.                         C533C0C0
           *AND.QS(ICF,ICI).LT.99999999.)SIQS=SIQS+QS(ICF,ICI)               0534C000
            IF(C(20,ICF).EQ.20.AND.Q(ICF,ICI).LT.0.)SOQ=SOQ+Q(ICF,ICI)       C535C0C0
            IF(C(21,ICF).EQ.21.AND.QS(ICF,ICI).LT.0.)SOQS=SOQS+QS(ICF,ICI)   C536C000
            IF(C(33,ICF).EQ.33.AND.W(ICF,ICI).LT.0.)SIW=SIW+W(ICF,ICI)       C537C0C0
            IF(C(34,ICF).EQ.34.AND.WS(ICF,ICI).LT.0.)SIWS=SIWS+WS(ICF,ICI)   C538C000
            IF(C(33,ICF).EQ.33.AND.W(ICF,ICI).GT.0.                          0539C000
           *AND.W(ICF,ICI).LT.99999999.)SOW=SOW+W(ICF,ICI)                   C54CC000
            IF(C(34,ICF).EQ.34.AND.WS(ICF,ICI).GT.0.                         C541C000
           *AND.WS(ICF,ICI).LT.99999999.)SOWS=SOWS+WS(ICF,ICI)               0542C000
      949   CONTINUE                                                         C5430000
            WSNET = SIWS+SOWS                                                0544C0C0
            WNET = SIW+SOW                                                   C545C000
            IF(SIQ.NE.0) THEF = WNET / SIQ                                   C546C0C0
            IF(SIQS.NE.C) THEF = WSNET / SIQS                                05470000
            WRITE(6,8833)SIQS,SOQS,SIWS,SOWS,WSNET,THEF                      C548C0C0
            WRITE(14,8833)SIQS,SOQS,SIWS,SOWS,WSNET,THEF                     C5490000
      8833  FORMAT(/,80('-'),/,25X,'C Y C L E   R E S U L T S',/,            055CC0C0
           */,' INPUT HEAT/MASS =',F10.4,10X,'OUTPUT HEAT/MASS   =',F10.4,   C5510CC0
           */,' INPUT WORK/MASS =',F10.4,10X,'OUTPUT WORK/MASS   =',F10.4,   05520000
           */,' NET WORK / MASS =',F10.4,10X,'THERMAL EFFICIENCY =',F10.4,   C553C0C0
           */,80('-'))                                                       C554C000
            WRITE(6,8768)                                                    0555C0C0
            WRITE(14,8768)                                                   0556CC00
      8768  FORMAT(//,'      WOULD YOU LIKE TO SOLVE THE SAME CYCLE WITH ',  C557CCC0
           */,'     NEW VALUES FOR SOME OF THE VARIABLES  ?',                0558C038
           */,' ***  TYPE IN EITHER  YES  OR  NO',/)                         C559C0C0
            READ(5,8505)LETTER                                               C56CC0C0
            WRITE(14,8505)LETTER                                             C561C032
            IF(LETTER.EQ.KYES.OR.LETTER.EQ.KYEES)  GOTO  7732                C562C0C7
            GO   TO   7523                                                   C563CCC7
      7732  NAR = 1                                                          C564CCC7
            LAF = I                                                          C565CC00
```

```
      C----------------------- INITIALIZING V.S.T.'S -----------------------05660034
             DO 8737 LV1 = 1 , 10                                            05670000
             DO 8737 LV2 = 1 , 100                                           05680000
      8737   C(LV2,LV1) = 0                                                  05690000
      C----------------------- RESTORING INPUT DATA ------------------------05700034
             DO 8739 ML2 = 1 , 100                                           05710023
             DO 8739 ML1 = 1 , LAF                                           05720023
             I =  ML1                                                        05730013
             F = I + 1                                                       05740012
             IF(F.GT.LAF) F = IONE                                           05750013
             IF(F.LT.5) IF5 = F + 5                                          05760013
             IF(DIX(ML2,F).EQ.VIL) GO TO  8738                               05770013
             J = ML2                                                         05780000
             XX = DIX(J,F)                                                   05790013
             A = F                                                           05800013
             CALL  SUBIN                                                     05810021
      C       WRITE(6,177)I,F,J,XX,A                                         05820037
      C       WRITE(14,177)I,F,J,XX,A                                        05830037
      C177    FORMAT(1X,'I,F,J,XX,A =  ',3I5,F9.2,I5)                        05840037
      8738   IF(DIX(ML2,IF5).EQ.VIL) GO TO  8739                             05850035
             J = ML2                                                         05860029
             XX = DIX(J,IF5)                                                 05870029
             A = IF5                                                         05880029
             CALL  SUBIN                                                     05890029
      C8749   IF(ML2.EQ.100) CALL CUT22                                      05900035
      8739   CONTINUE                                                        05910000
             GO  TO  7506                                                    05920000
      C--------------------------------------------------------------------05930000
      C-------------------- CHECKING FOR SOLVING A NEW PROBLEM -------------05940034
      C--------------------------------------------------------------------05950034
      7523   WRITE(6,8523)                                                   05960000
             WRITE(14,8523)                                                  05970000
      8523   FORMAT(/,80('#'),/,'  WOULD YOU LIKE TO SOLVE A NEW PROBLEM ?', 05980000
            */,' *** TYPE IN EITHER    YES    OR    NO  ',                   05990000
            */,80('#'),/)                                                    06000000
             READ(5,8505)LETTER                                              06010000
             WRITE(14,8505)LETTER                                            06020000
             IF(LETTER.EQ.NON.OR.LETTER.EQ.NOON)  GOTO  7520                 06030000
             GO TO  7501                                                     06040000
      7520   WRITE(6,8520)                                                   06050000
             WRITE(14,8520)                                                  06060000
      8520   FORMAT(///,80('*'),                                             06070000
            */,25('*'),'  S E E   Y O U   L A T E R  ',27('*'),              06080000
            */,80('*'))                                                      06090000
             STOP                                                            06100000
             END                                                             06110000
```